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OF

HUMAN PHYSIOLOGY:

WITH THEIR CHIEF APPLICATIONS TO PSYCHOLOGY, PATHOLOGY, THERAPEUTICS, HYGIÈNE, & FORENSIC MEDICINE.

BY

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ETC. ETC.

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7.

PREFACE TO THE FIFTH EDITION.

The issue of the Fourth Edition of the present work was attended with much apprehension on the part of the Author, lest the overgrown bulk which it had attained, in consequence of his desire to render every part of it as complete as possible, might prevent the continuance of that general demand, which it had been the good fortune of previous Editions to excite. It has been, therefore, a source of peculiar satisfaction to him, that the unprecedently-rapid sale of a large impression should have so promptly renewed the assurance of a kind appreciation of his labours, on the part of those to whom he most desires to render them acceptable. And the success which has thus attended them, has been an additional inducement to him to spare no pains to deserve a continuance of it.

In commencing the preparation of a New Edition, however, it was evident to him, that, as the dimensions of the volume altogether precluded any increase in the number of its pages, whilst their previous repletion equally prevented any augmentation of their capacity, no *addition* of new matter could be made, without a corresponding *omission* of old,—a proceeding which he could not bring himself to adopt. But having already been led, by the occurrence of the same difficulty in the case of his "Principles of General and Comparative Physiology," to determine upon the division of that work into two separate and independent treatises, on "General" and "Comparative Physiology" respectively, it seemed to him to be the simplest and most desirable plan, to *transfer* from the "Human" to the "General Physiology" such parts of the former as could with propriety be incorporated with the latter; thus effecting such a reduction in the size of the "Human," as might enable him to make any additions to it that the progress of Science should require; and at the same time rendering the "General" more comprehensive and complete in itself,

as well as a more appropriate companion either to the "Comparative" or to the "Human." These three books will henceforth constitute as many *independent* but *mutually-connected* Treatises, on the three great departments into which modern Physiology naturally divides itself; and the Author has only to hope, that he may be found to have thus devised the most appropriate method of meeting the numerous kind suggestions which have been made to him, in regard to the division of his inconveniently-bulky Volumes.

In accordance with the foregoing plan, the Second, Third, and Fifth Chapters of the last Edition of this work, which included a summary of Animal Chemistry, and of the Structure and Actions of the Animal Tissues, amounting in all to about 250 pages, have been omitted from the present. On the other hand, additions have been made, to the amount of above 70 pages; and these by no means constitute the whole of the new matter introduced, since many portions have been re-written, with little or no increase of bulk. It has been the Author's desire, on this as on former occasions, that his Treatise should represent his present convictions and opinions, as completely as if it were making its appearance for the first time; and he has accordingly subjected every part of it to a revision not less careful than that which he would have bestowed upon it, had it less recently passed under a similar scrutiny. Although the minor results of this revision, which are scattered through almost every part of the volume, would not be apparent save on a searching comparison, yet he trusts that they will be found to have increased the utility of the work; —those of more importance, however, he deems it well now to particularize.

In the Chapters which treat of the several Organic Functions, many important additions have been derived from the admirable work of MM. Bidder and Schmidt, "Die Verdauungssäfte und der Stoffwechsel," which contains the results of those elaborate researches on Digestion, Respiration, Secretion, and the Metamorphosis of Tissue, which have carried-on for several successive years in the Dorpat Laboratory. It may be thought, perhaps, by such as are conversant with this work, that the Author has not made sufficient use of the vast body of information which it supplies: but he must be permitted to remark, in the first place, that so many of the statements of these able Experimenters are in direct contradiction to those of others who had previously stood in good repute, as well as to generally-accepted Physiological doctrines, that it is yet doubtful on which side the truth lies; and, secondly, that even where their facts are not disputed, there is often so much doubt respecting the right interpretation of

them, and more especially in regard to their applicability to Man, that he has scarcely judged it expedient to admit such into a Treatise which especially aims at embodying the *certainties* of Physiological Science.

The portions of Chapter IV. which relate to the Glandulæ of the Absorbent System, and to the Vascular Glands, have been almost entirely re-written, in accordance with the improved knowledge of these bodies which has been recently attained, through the labours of various histological Anatomists and experimental Physiologists, especially Brucke, Kolliker, and H. Gray.

The part of Chapter IX. in which the Minute Anatomy and the Physiology of the Liver are discussed, has been brought into accordance, on most points, with the views entertained by Prof. Kolliker as to its structure, and with those of Dr C. Handfield Jones in regard to its actions: the Author being now convinced that the account of this organ given by Dr. Leidy and by Prof. Retzius, to which he had formerly seen reason to assent, is based on a wrong interpretation of the appearances presented, and that the liver really unites, as well structurally as functionally, the essential characters of a Vascular or Assimilating Gland, with those of an Excretory Gland.

In Chapter XI., on the Functions of the Cerebro-Spinal Nervous System, the Author has again seen reason to introduce very considerable modifications; these having reference for the most part, however, rather to the order of *succession* of the subjects, than to the *opinions* previously put-forth, —the latter, in fact, having received most satisfactory confirmation, alike from the accordance which has been expressed with them by many highly-competent judges, from the Author's own more matured reflections, and from certain occurrences of public notoriety which have afforded most remarkable exemplifications of them. It would have been scarcely possible, in fact, to conceive of any more apposite and convincing proof of that independent automatic activity of the Cerebrum, and of its involuntary influence in producing Muscular contraction, which the Author had formularized in the doctrine of "Ideo Motor action," than that which was afforded by the Epidemic of "Table turning" and "Table-talking," which began to spread through Europe just at the epoch of the publication of the former Edition, in which that doctrine was first distinctly developed. And some of the rarer phenomena of that Epidemic also afforded interesting illustrations of his doctrine of "Unconscious Cerebration;" the validity of which has been admitted by many eminent Psychologists who have no leaning whatever to what is commonly termed "Materialism." Not among the least valuable of the testimonies to

the general correctness of the Author's views, as to the relation of the Will to the Automatic operations of the Cerebrum, are those which he has received from individuals practically conversant with various departments of Education (especially Schools for the Reformation of Juvenile Delinquents), and with the Treatment of Insanity. In recasting, as a separate Section of this Chapter, all that relates to "The Mind and its Operations," the Author has derived many valuable suggestions and much assistance, in regard to the 'Perceptive and Intuitional Consciousness,' from the valuable "Elements of Psychology" of his friend Mr. J. D. Morell; whilst, for the extension of his notion of those states of feeling which constitute the essence of Emotions, from that of mere *pleasure* and *pain* to which he had previously limited them, to more varied forms of 'Emotional Sensibility,' as well as for the suggestion of that very appropriate term, he is indebted to his friend Dr Daniel Noble.* The whole of this Section has passed under the revision of the Rev W. Thomson (Fellow and Tutor of Queen's College, Oxford), the Author of the well-known "Outline of the Necessary Laws of Thought," for whose kindness in undertaking this labour in behalf of one almost a stranger to him, the Author has great pleasure in making this acknowledgment.

In Chapter XII. (part of the first section of which has been transferred to what seemed its more appropriate place in the last-mentioned division), the section on Vision has received several additions and modifications; the most important of which are derived from the researches of H. Muller on the Structure of the Retina, from the enquiries of Prof. Wheatstone into various points in the Physiology of Binocular Vision, and from the curious investigations made by Dr. Serre in regard to the subjective phenomena produced by pressure on the Eyeball.

From Chapter XIII., also, the section "On the Influence of Expectant Attention on Muscular Movements" has been for the most part removed into Chapter XI., where it completed the doctrine of Ideo-Motor action; whilst the small portion relating to the movements of the Organic Muscles has been transferred to Chapter XV. To this last Chapter has also been removed the account of the structure and relations of the Sympathetic System; so that it now embraces a summary of all the principal modes in which the Nervous System, or the Mind through its agency, affects the Organic Functions.

Various improvements, scarcely worth here particularizing, have been

* See his "Elements of Psychological Medicine," 2nd edit. p. 56. This little work, the Author (though not accepting everything it contains) would strongly recommend to all who are entering on the practice of their Profession.

made in Chapter XVI., on the Generative Function, the most important additions being a summary of Dr. Dalton's researches on the distinctions between the Corpus Luteum of simple Menstruation and that of Pregnancy, and a notice of certain curious circumstances attending the transmission of Parental characters to the Offspring, which have a direct bearing on the question of Marriage of near Relations.

Chapter XVIII., "On the Modes of Vital Activity Characteristic of different Ages," has been almost entirely written specially for this Edition; the subject, which had been only touched-on incidentally in the preceding, appearing to the Author to deserve, under every point of view, a more express consideration.

The entire number of Wood-Engravings has necessarily undergone some reduction, owing to the transference of no fewer than 82, which illustrated the structure of the Primary Tissues, to the "General Physiology." But as many as 46 new ones have been introduced, in addition to those which previously illustrated the subjects treated-of in the present volume; these having been for the most part drawn from the "Mikroskopische Anatomie" of Prof. Kolliker, and from the new edition of Prof. Wagner's "Icones Physiologicæ" now being brought-out under the able superintendence of Prof. Ecker.*

The Author trusts that it will be apparent, from the foregoing summary, that he has spared no pains to render the present Edition worthy of the favourable reception which has been accorded to its predecessors. In making his selection from the vast mass of results which have been recently accumulated by the diligent labours of Physiologists of various countries, he has been guided by the principle which he had previously expressed on several occasions;—that, namely, of not rashly introducing changes inconsistent with usually-received views,—nor, on the other hand, showing an unwillingness to adopt the statements of those who have taken adequate pains to arrive at accurate conclusions. "He trusts that he may be found"—*now*, as *then*,—"to have exercised a sound discretion, as to both what he has admitted, and what he has rejected; and that his work will appear to exhibit, on the whole, a faithful reflection of the present aspect of Physiological Science. He cannot venture to expect, however, that

* It is the Author's ambition to produce, when his other engagements may permit, some large original work, that shall do like credit, he trusts, to British Science. For the present, however, all his disposable time must be given to the completion of [illegible] undertakings among which the "General Physiology" will rightly claim his early attention, and to the preparation for publication of a series of original researches in another department of Biological Science, on which he has been for some time engaged.

he has succeeded in every instance, so that each of his readers will be in constant agreement with him; since it is impossible that they should all survey the subject from the same point of view."

In conclusion, the Author would repeat the remark with which he brought to a close the Preface to the first Edition (1842);—"that in a work involving many details, it is not to be expected that no error should have crept-in; but that he has endeavoured to secure correctness, by relying only upon such authorities as appeared to him competent, and by comparing their statements with such general principles as he considers well established. For the truth of those principles he holds himself responsible; for the correctness of the details, he must appeal to those from whom they are derived, and to whom he has generally referred. He hopes that he may not be found unwilling to modify either, when they have been proved to be erroneous; nor indisposed to profit by criticism, when administered in a friendly spirit."

University Hall, London, March, 1855.

CHAPTER V.

OF THE BLOOD; ITS PHYSICAL CHARACTERS, CHEMICAL COMPOSITION, AND VITAL PROPERTIES.

CHAPTER VI.

OF THE CIRCULATION OF THE BLOOD.

CHAPTER VII

OF RESPIRATION.

CHAPTER VIII.

OF NUTRITION.

CHAPTER IX.

OF SECRETION AND EXCRETION

CHAPTER X.

OF THE EVOLUTION OF LIGHT, HEAT, AND ELECTRICITY

CHAPTER XI.

OF THE FUNCTIONS OF THE CEREBRO-SPINAL NERVOUS SYSTEM.

CHAPTER XII.

OF SENSATION, AND THE ORGANS OF THE SENSES.

CHAPTER XIII.

OF MUSCULAR MOVEMENTS.

CHAPTER XIV.

OF THE VOICE AND SPEECH.

CHAPTER XV.

OF THE INFLUENCE OF THE NERVOUS SYSTEM ON THE ORGANIC FUNCTIONS.

CHAPTER XVI.

OF GENERATION.

CHAPTER XVII.

OF THE DIFFERENT BRANCHES OF THE HUMAN FAMILY, AND THEIR MUTUAL RELATIONS.

CHAPTER XVIII.

OF THE MODES OF VITAL ACTIVITY CHARACTERISTIC OF DIFFERENT AGES.

CHAPTER XIX.

OF DEATH

FIG.

9. Portion of the *mucous* layer of the germinal membrane, highly magnified; show that it is made-up of cells, whose borders are more distinct and more clo applied to each other than those of the serous layer, and whose contents more transparent (§ 888).

[The six preceding figures are after Bischoff ("Entwickelungsgeschichte Säugethiere," &c. (1842), "des Kaninchen-eies" (1842), — " Hunde-eies" (1845).]

10. Gravid Uterus of a Woman who had committed suicide in the seventh week pregnancy, laid open; *a*, os uteri internum; *b*, cavity of the cervi *c*, *c*, *c*, *c*, the four flaps of the body of the uterus turned back; *d*, *d*, inner surface of uterine decidua; *e*, *e*, decidua reflexa; *f*, *f*, external vill surface of the chorion; *g*, internal surface of the chorion; *h*, amni *i*, umbilical vesicle; *k*, umbilical cord; *l*, embryo; *m*, space betw chorion and amnion (§§ 862–864, and 890, 891). [After Wagner ("Icon Physiologicæ").]

PLATE II.

11. Uterine Ovum of Rabbit, showing the Area Pellucida, with the primitiv trace (§ 889).

12. More advanced Ovum, showing the incipient formation of the Vertebral column and the dilatation of the primitive groove at its anterior extremity (§ 889).

13. More advanced Embryo, seen on its ventral side, and showing the first develop ment of the Circulating apparatus. Around the Vascular Area is shown th terminal sinus, *a*, *a*, *a*. The blood returns from this by two superio branches, *b*, *b*, and two inferior, *c*, *c*, of the omphalo mesenteric veins, to the heart, *d*, which is, at this period, a tube curved on itself, and presenting the first indication of a division into cavities. The two aortic trunks appear, in the abdominal region, as the inferior vertebral arteries, *e*, *e*; from which are given-off the omphalo-mesenteric arteries, *f*, *f*, which form a network that distributes the blood over the vascular area. In the cephalic region are seen the anterior cerebral vesicles, with the two ocular vesicles, *g* (§§ 890, 892).

[The three preceding figures are from the works of Bischoff previously cited.]

PLATE III.

(To face page 6.)

Comparative View of the Skeleton of Man, and of that of the Orang Outan.

[After Owen ("Zoological Transactions," vol. i.).]

Fig. 13

LIST OF WOOD-ENGRAVINGS.

CHAPTER I.

OF THE DISTINCTIVE CHARACTERISTICS OF MAN.

1. By Cuvier and nearly all modern Zoologists, the various races of Mankind are included under one genus *Homo*, and this genus takes rank, in the classification of Mammalia, as a distinct order, Bimana, of which it is the sole representative. Of all the characters which distinguish Man from the inferior Mammalia, the possession of *two hands* is doubtless the most easily recognized, and at the same time the most intimately related to the general organization of the body; and there is none, therefore, which could be more appropriately selected as the basis of a distinctive designation of this order. At first sight it might be considered that the possession of only *two* hands, whilst Apes and Monkeys and their allies are designated as possessing *four*, is a character of inferiority; but such is not really the case; for none of these four hands are adapted to the variety of actions of which those of man are capable, and they are all in some degree required for support; so that whilst, in the higher forms of the Quadrumanous order, the extremities present a certain approximation in structure to those of Man, in the lower they gradually assimilate to the ordinary quadrupedal type. "That," says Cuvier, "which constitutes the *hand*, properly so called, is the faculty of opposing the thumb to the other fingers, so as to seize

Fig. 1.

Hand of *Man*, compared with anterior extremity of *Orang*

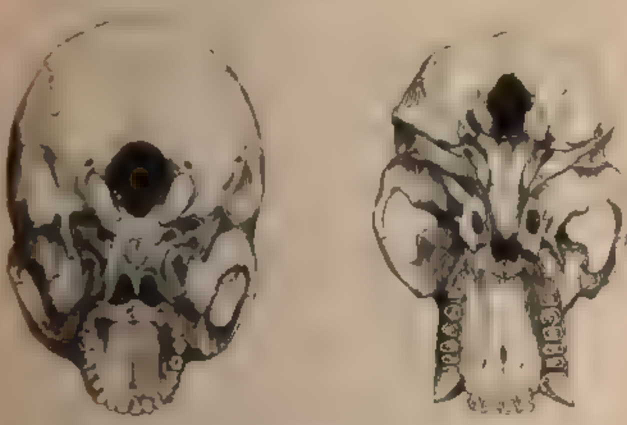
upon the most minute objects; a faculty which is carried to its highest degree of perfection in Man, in whom the whole anterior extremity is

free, and can be employed in prehension." The peculiar prehensile power possessed by Man, is chiefly dependent upon the size and power of the thumb, which is more developed in him, than it is in the highest Apes (Fig. 1). The thumb of the Human hand can be brought into exact opposition to the extremities of all the fingers, whether singly or in combination; whilst in those Quadrumana which most nearly approach man, the thumb is so short, and the fingers so much elongated, that their tips can scarcely be brought into opposition, and the thumb and fingers are so weak that they can never be opposed to each other with any degree of force. Hence, although well suited to cling round bodies of a certain size, such as the small branches of trees, &c., the extremities of the Quadrumana can neither seize very minute objects with such precision, nor support large ones with such firmness, as are essential to the dexterous performance of a variety of operations, for which the hand of Man is admirably adapted. There is much truth, then, in Sir C. Bell's remark that "we ought to define the hand as belonging exclusively to Man." There is in him, what we observe in none of the Mammalia which approach him in other respects, a complete distinction in the functional character of the anterior and posterior extremities; the former being adapted for prehension alone, and the latter for support and progression alone: and thus each function is performed in a much higher degree of perfection, than it can be when two such opposite purposes have to be united. For not only is the *hand* of Man a much more perfect prehensile instrument than that of the Orang or Chimpanzee, but his *foot* is a much more perfect organ of support and progression than theirs, being adapted to maintain his body in an erect position, alike during rest and whilst in motion (§ 5), an attitude which even the most anthropoid apes can only sustain for a short time, and with an obvious effort. The arm of the higher Apes has as wide a range of motion as that of Man, so far as its articulation is concerned; but it is only when the animal is in the erect attitude, that the limb can have free play. Thus the structure of the whole frame must be conformable to that of the hand, in the way that we find it to be in Man, in order that this organ may be advantageously applied to the purposes which it is adapted to perform. But it cannot be said with truth (as some have maintained) that Man owes his superiority to his hand alone; for without the *mind* by which it is directed, and the *senses* by which its operations are guided, it would be a comparatively valueless instrument. Man's elevated position is due to the superiority of his mind and of its material instruments conjointly; for if destitute of either, the human race must be speedily extinguished altogether, or reduced to a very subordinate grade of existence.

2. The next series of characters to be considered, are those by which Man is adapted to the erect attitude.—On examining his *cranium*, we remark that the occipital condyles are so placed, that a perpendicular dropped from the centre of gravity of the head would nearly fall between them, so as to be within the base on which it rests upon the spinal column. The foramen magnum is not placed in the centre of the base of the skull, but just behind it; so that the greater specific gravity of the posterior part of the head, which is entirely filled with solid matter, is compensated by the greater length of the anterior part, which contains many cavities. There is, indeed, a little over-compensation, which gives

a slight preponderance to the front of the head, so that it drops forwards and downwards when all the muscles are relaxed; but the muscles which are attached to the back of the head are far larger and more numerous than those in front of the condyles, so that they are evidently intended to counteract this disposition, and we find, accordingly, that we can keep up the head for the whole day, with so slight and involuntary an effort, that no fatigue is produced by it. Moreover, the plane of the foramen magnum, and the surfaces of the condyles, have a nearly horizontal direction when the head is upright; and thus the weight of the skull is laid vertically upon the top of the vertebral column.—If these arrangements be compared with those which prevail in other Mammalia, it will be found that the foramen and condyles are placed in the latter much nearer the back of the head, and that their plane is more oblique. Thus, whilst the foramen magnum is situated, in Man, just behind the centre of the base of the skull, it is found, in the Chimpanzee and Orang Outan, to occupy the middle of the posterior third (Fig. 2); and, as we descend through the scale of Mammalia, we observe that it gradually approaches the *back* of the skull, and at last comes nearly into the line of its longest diameter, as we see in the Horse. Again, in all Mammalia, except Man, the plane of the condyles is oblique, so that, even if the head were equally balanced upon them, the force of gravity would tend to carry it forwards and downwards. In Man, the angle which they make with the horizon is very small; in the Orang Outan, it is as much as 37°, and in the

Fig. 2.



View of the base of the Skull of *Man*, compared with that of the *Orang Outan*.

Horse, their plane is vertical, making the angle 90°. If, therefore, the natural posture of Man were horizontal, the plane of his condyles would be brought, like that of the Horse, into the vertical position, and the head, instead of being nearly balanced on the summit of the vertebral column, would hang at the end of the neck, so that its whole weight would have to be supported by some external and constantly-acting power. But for this, there is neither in the skeleton, the ligamentous apparatus, nor

the muscular system of Man, any adequate provision; so that in any oth
than the vertical position, his head, which is relatively heavier than th
of most Mammalia, would be supported with more difficulty and effi
than it is in any other animal.

3. The position of the *face* immediately beneath the brain, so that
front is nearly in the same plane as the forehead, is peculiarly char
teristic of Man; for the crania of the Chimpanzee and Orang, whi

Fig. 3.

Skeleton of *Gorilla*

approach nearest to that of Man, are rather posterior to, than above, t
face (Figs. 3, 5). The projection of the muzzle, taken in connection w
the obliquity of the condyles, is another evidence of want of perfect ad

tation to the erect posture; whilst the absence of prominence in the face of Man shows that none but the erect position can be natural to him. For supposing that, with a head formed and situated as at present, he were to move on all-fours, his face would be brought into a plane parallel with the ground, so that as painful an effort would be required, to examine with the eyes an object placed in front of the body, as is now necessary to keep the eyes fixed on the zenith; the nose would then be incapacitated for receiving any other odorous emanations, than those proceeding from the earth or from the body itself, and the mouth could not touch the ground, without bringing the forehead and chin also into contact with it. The oblique position of the condyles in the Quadrumana enables them, without much difficulty, to adapt the inclination of their heads either to the horizontal or to the erect posture; but the natural position, in the highest among them, is unquestionably one in which the spinal column is inclined, the body being partially thrown forwards, so as to rest upon the anterior extremities; and in this position, the face is directed forwards without any effort, owing to the mode in which the head is obliquely articulated with the spine (Fig. 3).

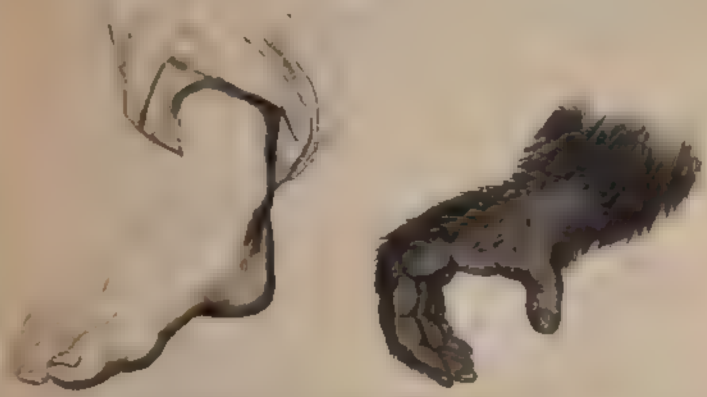
4. The *vertebral column* in Man, although not absolutely straight, has its curves so arranged, that, when the body is in an erect posture, a vertical line from its summit would fall exactly on the centre of its base. It increases considerably in size in the lumbar region, so as to be altogether somewhat pyramidal in form. The lumbar portion, in the Chimpanzee and Orang, is not of the same proportional strength, and contains but four vertebræ, instead of five. The processes for the attachment of the sacro-spinal muscles to this part, are peculiarly large and strong in Man; and this arrangement is obviously adapted to overcome the tendency, which the weight of the viscera in front of the column would have, to draw it forwards and downwards. On the other hand, the spinous processes of the cervical and dorsal vertebræ, which are in other Mammalia large and strong, for the attachment of the ligaments and muscles that support the head, have comparatively little prominence in Man, his head being nearly balanced on the top of the column.—The base of the Human vertebral column is placed on a sacrum of greater proportional breadth than that of any other animal; this sacrum is fixed between two widely expanded ilia, and the whole *pelvis* is thus peculiarly broad. In this manner the femoral articulations are thrown very far apart, so as to give a wide basis of support: and by the oblique direction of the pelvis, the weight of the body is transmitted almost vertically from the top of the sacrum to the upper part of the thigh bones. The pelvis of the anthropoid Apes is very differently constructed, as will be seen in the adjoining Plate, in which the skeleton of the Orang is placed in proximity with that of Man. It is much larger and narrower; its alæ extend upwards rather than outwards, so that the space between the lowest ribs and the crest of the iliac bones is much less than in Man; their surfaces are nearly parallel to that of the sacrum, which is itself longer and narrower; and the axis of the pelvis is nearly parallel with that of the vertebral column. The position of the Human femur, in which its head is most securely retained in its deep acetabulum, is that which it has when supporting the body in the erect attitude; in the Chimpanzee and Orang, its analogous position is at an oblique angle to the long axis of the pelvis, so that

the body leans forwards in front of it; in many Mammalia, as in the Elephant, it forms nearly a right angle with the vertebral column; and in several others, as the Horse, Ox, &c., the angle which it makes with the axis of the pelvis and vertebral column is acute. In this respect, then, the skeleton of Man presents an adaptation to the erect posture, which is exhibited by that of no other Mammal.

5. The *lower extremities* of Man are remarkable for their length, which is proportionably greater than that which we find in any other Mammalia, except the Kangaroo tribe. The chief difference in their proportional length, between Man and the semi-erect Apes, is seen in the thigh; and it is from the relative length of this part in him, as well as from the comparative shortness of his anterior extremities, that his hands only reach the middle of his thighs, whilst in the Chimpanzee they hang on a level with the knees (Fig. 3), and in the Orang they descend to the ankles (PLATE). The Human femur is distinguished by its form and position, as well as by its length. The obliquity and length of its neck still further increase the breadth of the hips, whilst they cause the lower extremities of the femora to be somewhat obliquely directed towards each other, so that the knees are brought more into the line of the axis of the body. This arrangement is obviously of great use in facilitating the purely *biped* progression of Man, in which the entire weight of the body has to be alternately supported on each limb; for if the knees had been kept further apart, the whole body must have been swung from side to side at each step, so as to bring the centre of gravity over the top of each tibia, as is seen to a certain extent in the female sex, whose walk, owing to the greater breadth of the pelvis and the separation between the knees, is less steady than that of the male. There is a very marked contrast between the knee-joint of Man, and that of even the highest Apes. In the former, the opposed extremities of the femur and the tibia are expanded, so as to present a very broad articulating surface; and the internal condyle of the femur being the longer of the two, they are in the same horizontal plane in the usual oblique position of that bone; so that by this arrangement, the whole weight of the body, in its erect posture, falls vertically on the top of the tibia, when the joint is in the firmest position in which it can be placed. The knee-joint of the Orang, on the other hand, is comparatively deficient in extent of articulating surface; and its whole conformation indicates that it is not intended to serve as more than a partial support.—The human foot is, in proportion to the size of the whole body, larger, broader, and stronger, than that of any other Mammal save the Kangaroo. Its plane is directed at right angles to that of the leg; and its sole is concave, so that the weight of the body falls on the summit of an arch, of which the os calcis and the metatarsal bones form the two points of support. This arched form of the foot, and the natural contact of the os calcis with the ground, are peculiar to Man alone. All the Apes have the os calcis small, straight, and more or less raised from the ground, which they touch, when standing erect, with the outer side only of the foot: whilst in animals more remote from Man, the os calcis is brought still more into the line of the tibia; and the foot being more elongated and narrowed, only the extremities of the toes come in contact with the ground. Hence Man is the only species of Mammal, which can stand upon one leg. All the points in which the feet of the anthropoid

Apes differ from his, are such as assimilate them to the *manual* type of conformation, and enable them to serve as more efficient prehensile organs; whilst they diminish their capacity to sustain the weight of the body, when it simply rests upon them (Fig. 4).

Fig. 4.



Foot of *Man*, compared with posterior extremity of *Orang*

6. There is a considerable difference in the form of the *trunk*, between Man and most other Mammalia, for his thorax is expanded laterally, and flattened in front, so as to prevent the centre of gravity from being carried too far forwards, and his sternum is short and broad. Between the bony walls of the thorax and the margin of the pelvis, a considerable space intervenes, which is occupied solely by muscles and tegumentary membranes, and these would be quite insufficient to sustain the weight of the viscera, if the habitual position of the trunk had been horizontal.—In these particulars, however, the most anthropoid Apes agree more or less completely with Man.

7. Returning now to the *skull* for a more minute examination, we observe that the cranium of Man is distinguished from that of the anthropoid Apes, not merely by its great capacity, but also by its smoothness; its surface being almost entirely deficient in those ridges for the attachment of muscles, which are remarkably strong in both the Chimpanzee and the Orang, and which impart to its configuration somewhat of a carnivorous character. This aspect is strengthened by the great depth of the temporal fossa, and by the extent and strength of the zygomatic arch, features that are most remarkably developed in the *Troglodytes gorilla*, a newly-discovered species of Chimpanzee, which is regarded by Prof. Owen as presenting on the whole the nearest approach to the human type (Fig. 3). Moreover, the jaws in even the most degraded races of Man project far less from the general plane of the face, than they do in the Apes, and his teeth are arranged in a continuous series, without any hiatus or any considerable difference in length: whilst all the Apes, in their adult state at least, are furnished with canine teeth of extraordinary length, between the sockets of which and those of the adjoining teeth (anteriorly in the upper jaw, and posteriorly in the lower,) there is a vacant space

or diastema. Even in the most prognathous Human skulls, moreover, the incisors meet each other much more nearly in the same axis, than they do in the anthropoid Apes, in which they form an angle with each other that is not nearly so divergent. The fusion of the intermaxillary or premaxillary bones with the superior maxillary, at an early period of fœtal life, is a remarkable character of the Human cranium, as distinguishing it from that of the Apes, in which the intermaxillary bones remain separate to a much later period, sometimes differing also, in a very marked degree, in size and shape. Thus in the *Troglodytes gorilla*, these bones are not only remarkable for their prominence, but also for their upward extension round the nostrils, so that they completely exclude the maxillary bones from their borders, and form the basis of support for the nasal bones, and although they coalesce with the maxillaries at and near the alveolar portion, they remain separate elsewhere. The lower jaw of Man is remarkable for that prominence at its symphysis, which forms the chin; and although this, also, is least developed in the most prognathous human crania, yet it is never so deficient as it is in the lower jaw of the Chimpanzee and Orang.—It is curious to observe that the skulls of the *young* of Man and of the anthropoid Apes resemble one another much more than do those of the *adults*, each tending to diverge, in its advance towards full development, from a type which seemed almost similar in both (Figs. 5, 6, 7). It is at the time of the second dentition, that the muzzle of the anthropoid Apes acquires its peculiar elongation, and consequent projection in front of the forehead (Figs. 2, 5), and the whole cast of the features is altered at the same time, so that it approaches much more to that of the lower Quadrumana, than would be supposed from observation of the young animal only.* In the Human subject, on the other hand, we see that in the advance from childhood to adult age, there is a progressive enlargement of the face, in proportion to the capacity of the cranial cavity.†

8. The great size of the *cranial* portion of the skull in Man, as compared with the *facial*, produces a marked difference between his 'facial angle,' and that of even the highest Quadrumana. According to Camper, who first applied this method of measurement, the 'facial angle' of the average of European skulls is 80°, whilst in the ideal heads of the Grecian gods it is increased to 90°, on the other hand, in the skull of a Kalmuck he found it to be 75°, and in that of a Negro only 70°; and applying the same system of measurement to the skulls of Apes, he found them to range from 64° to 60°. But these last measurements were all taken from young skulls, in which the forward extension of the jaws, which takes place on the second dentition, had not yet occurred. In the adult Chimpanzee, as Prof. Owen has shown, the 'facial angle' (Figs. 5, 6, 7, A O P), is no more than 35°, and in the adult Orang only 30°; so that instead of the Negro being nearer to the Ape than to the European, as Camper's estimate would make him, the interval between the most

* None but young specimens of the Chimpanzee and Orang Outan have ever been brought alive to this country; and they have never long survived the period of their second dentition.

† See Prof. Owen's Papers on the Anatomy of the Orang and Chimpanzee, in the "Zoological Transactions," vols. i. and ii., and Prof. Vrolik in the Art. *Quadrumana* in the "Cyclopedia of Anatomy and Physiology," vol. iv.

and the other muscles which tend to keep the leg erect upon the foo form a much more prominent 'calf' than is seen either in the mo anthropoid Apes, or in any other animal. So, again, the extensors of th leg upon the thigh are much more powerful than the flexors, a characte which is peculiar to Man. The glutæi, by which the pelvis is kept ere upon the thigh, are of far greater size than is elsewhere seen. Th superior power of the muscles tending to draw the head and spine back wards, has been already referred-to. Among the differences in the attach ment of individual muscles, it may be noticed that the 'flexor longus pollic pedis' proceeds in Man to the great toe alone, on which the weight of th body is often supported; whilst it is attached in the Chimpanzee an Orang to the three middle toes also. The 'latissimus dorsi' is destitute i Man of that prolongation attached to the olecranon, which is found i the lower Mammalia, and which exists even in the Chimpanzee, probabl giving assistance in its climbing operations. The larger size of th muscles of the thumb, is, as might be expected, a characteristic of th hand of Man; although the number of muscles by which that digit i moved, is the same in the Chimpanzee as in the Human subject. Th existence of the 'extensor digiti indicis,' however, as a distinct muscle, i peculiar to Man.

10. The *Visceral* apparatus of Man presents very few characteristi peculiarities, by which it can be distinguished from that of the highe Quadrumana; among the most remarkable is the absence of the larynge pouches, which exist even in the Chimpanzee and Orang Outan, as dila tations of the laryngeal ventricles.—Of the anatomy of the last-named animals in their *adult* condition, however, we know as yet too little to enable its conformity to that of Man to be confidently pronounced-upon.

11. The *Brain* of Man does not differ so much in conformation from that of the Chimpanzee and Orang, as the superiority of his mental endowments might have led us to anticipate. The following are the principal differences which it seems to present:—1. The mass of the entire brain is considerably larger in proportion to that of the body, and in proportion also to the diameter of the spinal cord and of the nerves which are connected with it.—2. In the external configuration of the Cerebrum, we notice that its *anterior* lobes project further beyond the Rhinencephalon, or Olfactive Ganglion, than they do in the highest Quadrumana; a difference which is well marked in the sectional contour of the brain-case, the rhinencephalic fossa of the Orang (Fig. 5, *rh*) being at its most anterior part, whilst even in the least elevated forms of the Human skull, this fossa (of which the cribriform plate of the ethmoid bone constitutes the floor) has no inconsiderable part of the cranial cavity in front of it (Fig. 7, *rh*).—3. The *posterior* lobes also are more developed, so as to project further beyond the Cerebellum than they do in any of the Quadrumana; the convolutions are more numerous, and the sulci are deeper.—4. On examining the internal structure, it is found that the peripheral layer of grey matter is thicker, the corpus callosum extends further backwards, and the posterior cornua of the lateral ventricles are relatively longer and larger than they are in any Quadrumana.—5. The Cerebellum, also, is proportionally larger.

12. The small size of the face of Man, compared with that of the cranium, is an indication that in him the *senses* are subordinate to the

for everywhere, throughout the Organized Creation, do we observe that the most elevated forms are those which go through the longest preparatory stages, and of which the evolution is most dependent upon the assistance afforded by the parental organism during its earlier periods. The peculiar prolongation of this state of dependence in the Human species, has a most important and evident effect upon the social condition of the race; being, in fact, the chief source of family ties, and affording the opportunity for those processes of education, direct and indirect, which transmit to the rising generation the influence of the intellectual culture and moral training of the past.

15. Still, however widely Man may be distinguished from other animals by these and other particulars of his structure and economy, he is yet more distinguished by those *mental* endowments, and by the habitudes of life and action thence resulting, which must be regarded as the essential characteristics of humanity. It is in adapting himself to the conditions of his existence, in providing himself with food, shelter, weapons of attack and defence, &c., that Man's intellectual powers are first called into active operation; and when thus aroused, their development has no assignable limit. The Will, guided by the intelligence, and acted-on by the desires and emotions, takes the place in Man of the Instinctive propensities which are the usual springs of action in the lower animals; and although, among the most elevated of these, a high amount of Intelligence is exhibited, yet its operations seem to be always directly attributable to external suggestions, present or remembered; and the character never rises beyond that of the child. In fact, the correspondence between the psychical endowments of the Chimpanzee, and those of a Child of three years old who has not yet begun to speak, is very close. One of the most important aids in the use and development of the Human Mind, is the capacity for *articulate speech*; of which, so far as we know, Man is the only animal in possession. There is no doubt that many other species have certain powers of communication between individuals; but these are probably very limited, and of a kind more allied to "the language of signs," than to a proper verbal language. In fact, it is obvious that the use of a language composed of a certain number of distinct sounds, combined into words in a multitude of different modes, requires a certain power of abstraction and generalization, in which it appears that the lower animals are altogether deficient. So, again, verbal language affords the only means whereby abstract ideas can be communicated; and those who have perused the interesting narrative given by Dr. Howe of his successful training of Laura Bridgeman, will remember how marked was the improvement in her mental condition, from the time when she first apprehended the fact that she could give such expression to her thoughts, feelings, and desires, as should secure their being comprehended by others.

16. The *capacity for intellectual progress* is a most remarkable peculiarity of Man's psychical nature. The instinctive habits of the lower Animals are limited, are peculiar to each species, and have immediate reference to their bodily wants. Where a particular adaptation of means to ends, of actions to circumstances, is made by an individual, the rest do not seem to profit by that experience; so that, although the instincts of particular animals may be modified by the training of man, or by the

which it here operates; and to this state,—a state of more intimate communion of mind with mind, and of creatures with their Creator,—he is encouraged to aspire, as the reward of his improvement of the talents here committed to his charge.

CHAPTER II.

GENERAL VIEW OF THE FUNCTIONS OF THE HUMAN BODY.

1. *Of the Mutual Dependence of its Vital Actions.*

18. The idea of *Life*, in its simplest acceptation, is that of *Vital Activity;* and obviously, therefore, involves that of *change*. We do not consider any being as *alive*, which is not undergoing some continual alteration, however slow and obscure, that may be rendered perceptible to the senses.* This alteration may be evidenced by the *growth* and *extension* of the organic structure, or by *molecular changes* in its substance which do not produce any ostensible increase; or it may be most obviously manifested in *movements* such as cannot be attributed to any physical cause. The Life of any complex organism, such as that of Man, is in fact the aggregate of the Vital Activity of all its component parts; and no fact has been more clearly ascertained by modern Physiological research, than this,—that each elementary part of the fabric has its own independent power of growth and development, that it has its own proper term of existence, and that it goes through its own sequence of vital actions, in virtue of the endowments which it derived from the tissue that evolved it, and of the influences to which it is subjected during the progress of its existence. Not only might this mutual independence be inferred from general considerations; its existence is easily proved by observation and experiment. There are a variety of cases in which the 'molecular' life of individual parts remains, long after 'somatic' death, (or death of the body as a whole) has taken place (CHAP. XIX); and not only may vital activity be sustained in a part completely separated from the body, by the maintenance of the circulation of blood through it, but vital endowments which had partially or completely ceased to manifest themselves in consequence of the cessation of the circulation, may be restored by its re-establishment. The occasional reunion of a member which has been entirely separated, when decomposing changes have

* If change be essential to our idea of life, it may be asked what is the condition of a Seed, which may remain unaltered during a period of many centuries, vegetating at last when placed in favourable circumstances, as if it had only ripened the year before. Such a seed is not *alive*, for it is not performing any vital operations. But it is not dead, for it has undergone no disintegration; and it is still capable of being aroused into active life, by the application of the appropriate stimuli. The most correct designation of its state, seems to be *dormant vitality*. The condition of an Animal reduced to a state of complete torpidity and inaction is precisely analogous; into such a condition, the Frog may be brought by cold, and the Wheel-animalcule by desiccation. (See PRINC. OF GEN. PHYS.) And the condition of a Human being, during sleep, is precisely similar, so far as his psychical powers are concerned: he is not then a feeling, thinking Man, but he is capable of feeling and thinking when his brain is restored to a state of activity, and its powers are called into operation by the impressions of external objects.

But it is very important to remark, that the growth of the more *permanent* parts of the structure is only attained by the continual development, decay, and renewal of parts, whose existence is *temporary*. No fact is better established in Vegetable Physiology, than the dependence of the formation of wood upon the action of the leaves. It is in their cells that those important changes are effected in the sap, by which it is changed from a crude watery fluid containing very little solid matter, to a viscid substance including a great variety of organic compounds, destined for the nutrition of the various tissues. The 'fall of the leaf' results merely from the death and decay of its tissue; as is evident from the fact, that, for some time previously, its regular functions cease, and that instead of a fixation of carbon from the atmosphere, there is a liberation of carbonic acid (a result of their decomposition) in large amount.* Now this process takes place no less in 'evergreens' than in 'deciduous' trees, the only difference being, that the leaves in the latter are all cast-off and renewed together, whilst in the former they are continually being shed and replaced, a few at a time. It appears as if the nutritious fluid of the higher Plants can *only* be prepared by the agency of cells whose duration is brief, for we have no instance in which the tissue concerned in its elaboration possesses more than a very limited term of existence. But by its active vital operations, it produces a fluid adapted for the nutrition of parts which are of a much more solid and permanent character, and which undergo little change of any kind subsequently to their complete development; this want of tendency to decay being the result of the very same peculiarity of constitution, as that which renders them unfit to participate in the proper vital phenomena of the organism. Thus the final cause or purpose of all the Nutritive functions of the Plant, so far as the *individual* is concerned, is to produce an indefinite extension of the dense, woody, almost inert and permanent portions of the fabric, by the continued development, decay, and renewal of the soft, active, and transitory cellular parenchyma. —The Nutritive functions, however, also supply the materials for the continuance of the *race*, by the generation of new individuals; since a fresh germ cannot be formed, any more than the parent-structure can be extended, without organizable materials, prepared by the assimilating process, and supplied to the parts in which active changes are going-on.

21. On analysing the operations which take place in the *Animal* body, we find that a large number of them are of essentially the same character with the foregoing, and differ only in the conditions under which they are performed; so that we may, in fact, readily separate the *Organic* functions, which are directly concerned in the development and maintenance of the fabric, from the *Animal* functions, which render the individual conscious of external impressions, and capable of executing spontaneous movements. The relative development of the organs destined to these two purposes, differs considerably in the several groups of Animals. The life of a Zoophyte is upon the whole much more 'vegetative' than 'animal;' and we perceive in it, not merely the very feeble development of those powers which are peculiar to the Animal kingdom, but also that tendency to indefinite extension which is characteristic of the Plant. In the Insect we have the opposite extreme; the most active powers of

* See "Principles of Comparative Physiology," §§ 265, 339.

aerated blood also serves to transmit oxygen, which is introduced by t Respiratory process; and it has further for its office, to convey away t products of that decomposition of the Muscular and Nervous tiss which results from their functional activity, these products being desti to be separated by the Respiratory and other Excreting operations. T regular maintenance of the functions of Animal life is thus enti dependent upon the due performance of the Nutritive operations; a c sideration of great importance in practice, since a very large proportion what are termed 'functional disorders' (of the Nervous system especial are immediately dependent upon some abnormal condition of the Bloo

24. But there also exists a connection of an entirely reverse ki between the Organic and the Animal functions; for the conditions Animal existence render the former in great degree dependent on t latter. In the acquisition of food, for example, the Animal has to ma use of its senses, its psychical faculties, and its power of locomotion, obtain that which the Plant, from the different provision made for support, can derive without any such assistance; moreover, for t ingestion of the food, and for its propulsion along the alimentary ca Muscular action is required, this being employed under the directi of Nervous agency at the oral and anal orifices; and thus we see th the change in the conditions required for the appropriation of food Animals, has rendered necessary the introduction of additional eleme into the apparatus, to which nothing comparable was to be found Plants. Again in the function of Respiration, as performed in Man a the higher animals, the Nervous and Muscular systems are alike involve for the movements by which the air in the lungs is being continual renewed, are dependent upon the action of both; and those by which t blood is propelled through the respiratory organs, are chiefly occasion by the contractility of a muscular organ, the heart. Such movemen however, as are thus immediately connected with the maintenance of t Organic functions, do not depend upon the *will*, and may even be pe formed without our *consciousness;* they can scarcely be regarded, ther fore, as forming part of our proper Animal life; and the only essenti difference which they present, from those which are occasionally perform by Plants (especially such as exhibit the transmission of the effect of stimulus to some distance,—the folding of the leaves of the Mimosa, the closure of the fly-trap of the Dionæa, for example), consists in t instrumentality through which they are performed,—this being Animals a peculiar Nervous and Muscular apparatus, whilst in Plants is only a modification of the ordinary structure.

25. From what has been said, then, it appears that all the functions the Animal body are so completely bound up together, that none can suspended without the cessation of the rest. The properties of all th tissues and organs are dependent upon their regular Nutrition, by a du supply of perfectly-elaborated blood; this cannot be effected, unless th functions of Circulation, Respiration, and Excretion, be performed wit regularity,—the first being necessary to distribute the supply of nutritio fluid, the second being requisite for its oxygenation, and being als needed, in conjunction with the third, to free it from the impuritie which it contracts during its circuit. The Respiration cannot be main tained, without the integrity of a certain part of the Nervo-muscul

2. *Functions of Vegetative Life.*

26. As a certain change of composition of the Organized fabric i necessary condition of every manifestation of its Vital activity, it obviously requisite that a provision should exist for the replacement, new matter, of all those particles, which, having lost their vital endo ments, are in process of return to the condition of inorganic matt And hence, of course, every increase in the activity of the Animal fun tions becomes a source of augmented demand for nourishment; provid at least, that such increase does not go to the extent of exhausting t vital energies, and thus of preventing the due performance of the Nut tive functions. A constant supply of Aliment is therefore needed the *maintenance* of the body, after it has arrived at its full developme The effects of the process of waste and decay, uncompensated by that renovation, are seen in starvation and in diseases of exhaustion (§ 70-75 in which there is a gradual diminution in the bulk of nearly all t tissues of the body, so that, before death supervenes, the total reducti in weight is very considerable. But in the *growing* state of the organis there is, of course, an additional demand for Aliment, to supply t materials for the extension which is continually taking place in it. Th however, does not make so great a difference as it might appear to do, the supply of food which is required. For if the absolute *additi* which is made by growth to the body in any given time, be compar with the amount of *change of composition* which takes place in the sa period,—the latter being judged of by the quantity of food consume and by the amount of excrementitious matter which passes-off by th lungs, liver, kidneys, skin, &c.—it will be found to bear but a very sma proportion to it. The fact is rather, that, during the whole period o growth, there is (so to speak) a continual re-modelling of the enti fabric; the life of each part being brief, in order that its renovation ma be effected on a somewhat different scale. And thus it happens tha children require a much larger amount of food in proportion to the bulk, than that which suffices for adults. On the other hand, in old per sons, the life of each part is comparatively slow; its vital operation are deficient in activity; and the processes of waste and the demand fo food are proportionally retarded (CHAP. XVIII.)

27. But another and most important source of demand for food, i Man and warm-blooded animals generally, arises out of the requirement of the *combustive* process, whereby the Heat of the body is maintained This demand will vary, *cæteris paribus*, with the amount of heat to b generated, which bears a direct proportion to the depression of th external temperature, the standard of the body itself being fixed. Henc external cold comes to be a source of demand for food, whilst artificial warmth may be made to take the place of the nourishment otherwise required for this purpose; as has been shown by the remarkable experi ments of Chossat hereafter to be referred-to (§ 70, and CHAP. X., Sect. 2). —But if the amount of exercise taken be very considerable, especially in warm climates, where the demand for the production of Heat is reduced to its minimum, a sufficient amount of *pabulum* for the respiratory pro cess may be provided by the disintegration of the nervo-muscular appa ratus, without any special supply being required.

nutritive components, being actually *dissolved* by the gastric juice, are th prepared for immediate absorption ; but others require the admixtur the biliary and pancreatic secretions, whereby various changes are effec in their condition, which prepare them also for being received into t circulating system. The nutritious portion being gradually taken-up the Blood-vessels and by the Absorbent vessels (or Lacteals), which distributed on the walls of the alimentary canal, the indigestible residu propelled along the intestinal tube by the simple contractility of its wa undergoing at the same time some further change, by which the nutrit materials are still more completely extracted from it. And at last, t excrementitious matter,—consisting not only of the insoluble portion the food taken into the stomach, but also of part of the secretion of t liver, and of that of the mucous surface of the intestines and of th glandular follicles,—is voided from the opposite extremity of the can by a muscular exertion, which is partly reflex, like that of degluti but is partly voluntary, especially (as it would appear) in Man. T whole of this series of operations, by which the nutritive materials prepared for being absorbed, may be considered as constituting the fu tion of *Digestion*.

31. The introduction of the nutritive materials thus prepared, in the vessels which convey them to the tissues, constitutes the function *Absorption*. But these materials undergo important changes in th progress towards the centre of the circulation, whereby they are broug more nearly to the condition of true Blood; and these changes designated by the term *Assimilation*.—There seems no doubt that flu containing saline, albuminous, or other matters in a state of comple solution, may be absorbed by the Blood vessels with which the muco membrane of the alimentary canal is so copiously supplied; and th simple process of imbibition probably takes place according to the ph sical laws of Endosmose. But the selection and absorption of some the nutritive materials appear to be performed, not by *vessels*, but b the specific vital endowments of *cells* (§ 121), which subsequently yie up their contents to the Lacteals. The fluid thus absorbed, which no receives the name of Chyle, is propelled through the Lacteals by th contractility of their walls; aided in part, perhaps, by a *vis a terg* derived from the force of the absorption itself. -With the reception the nutritious food into the vessels, commences its real preparation f Organization. Up to that period, it cannot be said to be in any degr *vitalized*, the changes which it has undergone being only of a chemic and physical nature, and such as merely *prepare* it for subsequent assim lation. But in the passage of that which has been taken up by th Blood-vessels, through the Liver, very important alterations are effected i its condition, whereby it is brought to a state more nearly correspondin with true Blood. And in like manner, the Chyle, in passing throug the long and tortuous system of absorbent vessels and glands, undergoe changes which, with little chemical difference, manifest themselves by decided alteration in its properties; so that the chyle of the Thoraci duct is evidently a very different fluid from the chyle of the Lacteal approaching much nearer to blood in its general characters. Thes characters are such as indicate that the process of organization an vitalization has commenced; as may be judged alike from the micro

blood to particular parts and organs, as we see in the acts of blushing and erection.

33. Upon the circulation of the Blood through all parts of the fabric, depends in the first place the *Nutrition* of the tissues. Upon this subject, formerly involved in the greatest obscurity, much light has recently been thrown by Microscopic discovery; it being now understood, that the continued growth and renewal of each tissue is effected by a continuation of a process essentially similar to that by which it was first developed. The greatest difficulty, in the present condition of our knowledge, is to comprehend the reason why such a variety of products should spring-up in the first instance, when the cells in which they all originate, appear to be so exactly alike. The important discoveries now referred-to, are not confined to healthy structures, for it has been ascertained, that diseased growths have a similar origin and mode of extension; and that the *malignant* character assigned to Schirrus, Medullary Sarcoma, and other such productions, is partly connected with the fact, that they are composed of cells which undergo little metamorphosis, and retain their reproductive power; so that from a single cell, as from that of a Vegetable Fungus, a large structure may rapidly spring up, the removal of which is by no means attended with any certainty that it will not speedily re-appear, from some germs left in the system.—The independent vitality of the cells in which all organized tissues originate, might be of itself a satisfactory proof, that in Animals, as in Plants, the actions of Nutrition are effected by the powers with which they are individually endowed; and that, whatever influence the Nervous system may have upon them, its agency is not essential to their performance. Moreover, it is certain that no formation of nervous matter takes place in the embryonic structure, until the processes of Organic life have been for some time in active operation. The influence which the Nervous System is known to have upon the function of Nutrition, is probably exerted in two ways; first, through its power of regulating the diameter of the arteries and capillaries, by which it controls in some degree the afflux of blood; and secondly, through the more direct relation of the Nervous force to those other forms of Vital agency, which manifest themselves in the growth, development, and maintenance of the living tissues. (See PRINC. OF GEN. PHYS.)

34. The continual disintegration to which the living tissues are subject, from the various causes already referred-to, renders it necessary that a means should be provided for conveying away the waste, as well as for supplying the new material. This is partly effected by the Venous circulation; which takes-up a large part of the products of incipient decomposition, and conveys them to organs of *Excretion*, by which they may be separated and cast-forth from the body. The first product of the decay of all organized structures, is *carbonic acid;* and this is the one which is most constantly and rapidly accumulating in the system, and the retention of which, therefore, within the body, is the most injurious. Accordingly we find a most important organ—the Pulmonary apparatus—adapted to remove it; and to this the whole current of Venous blood passes, before it is again sent through the system. The efficient performance of this function of *Respiration* is so essential to the well-being of warm-blooded animals, that a special heart is provided for propelling the

tissues; and it combines this with other elements, into a secretion w is of great importance in the digestive process. The hepatic circul however, is not kept-up by a distinct impelling organ; but the ve blood from the abdominal viscera (and, in the lower Vertebrata, from the posterior part of the body) passes through the liver o return to the heart.—But further, all animal substances have a tend during their decomposition, to throw-off nitrogen, as well as car and this nitrogen, in combination with other elements, forms peculiar *azotized* compounds, which it is the special function of Kidney to eliminate from the circulating fluid. The most charactes of these in Man, namely *urea*, contains a larger proportion of nitr than is found in any other organic compound, and is identical i chemical nature with cyanate of ammonia. Its production seem great part to depend upon the disintegration of the Muscular tissue; there is also evidence that it may result from the retrograde meta phosis of Albuminous or even of Gelatinous matters circulating in blood. The action of the Kidneys, which also serve as emunctories various soluble matters (especially saline compounds) whose accum tion in the blood would be injurious, is equally essential to the tinued performance of the other vital functions, with that of the l and liver; since death invariably follows its suspension, unless other means be provided by Nature (as occasionally happens), for separation of its characteristic excretion from the circulating bloo But further, the regulation of the amount of fluid in the vessel provided in a kind of *safety-valve* structure, existing in the Kidn which readily permits the escape of aqueous *fluid* from the capill vessels, into the urinary canals, by a process of physical transudati which is altogether distinct from the secretion of that *solid* mat which it is the office of the kidneys to separate from the circulat blood. Hence, if the excretion of fluid from the skin be checked cold, so that an accumulation would take place in the vessels, the creased pressure within them causes an increased escape of water throu the kidneys.

36. The various Secretions which have not already been adverted appear for the most part to have for their object the performance of so special function *in* the system, rather than the conveyance *out* of it any substances which it would be injurious to retain. This is the ca for example, in regard to the secretion of the Lachrymal, Salivary, a Mammary Glands, as well as with that of the Mucous and Serous Me branes. The excretion of fluid from the Cutaneous surface, howev appears to answer two important purposes, the removal from the bo of a portion of its superfluous fluid, containing products of decompositio —and the regulation of its temperature. Just as, by the action of t Lungs, the conditions are supplied, by which the temperature of the bo is kept-up to a certain standard, so, by that of the Skin, this is prevent from rising too high; for by the continual exudation from its surface, fluid which has to be carried-off by evaporation, a degree of cold is gen rated, which keeps the calorific processes in check; and this exudati is augmented in proportion to the elevation of the external temperatu which seems, in fact, the direct stimulus to the process.—In all forms *true* Secretion, the selection of the materials to be separated from th

39. The process of *Generation*, like that of Nutrition, has been recently involved in great obscurity; and although it cannot be s be yet fully elucidated, it has been brought, by late investigation more within our comprehension, than was formerly deemed po The close connection between the Reproductive and Nutritive opera both as regards their respective characters, and their dependence one another, has long been recognized, and it is now rendered more evident. Nutrition has not been unaptly designated, "a perp reproduction," and the expression is strictly correct. In the formed organism, the supply of alimentary material to every part o fabric enables it to produce a tissue resembling itself, thus we ordin find true bone produced only in continuity with bone, nerve with n muscle with muscle, and so on. Hence it would appear that, wh portion of tissue has once taken-on a particular *kind* of action, it tinues to reproduce itself on the same plan. But in the proper Ge tive process it is different. A single cell is generated by certain liminary actions, from which cell, all those which subsequently com the embryonic structures, take their origin; and it is not until a period, that any distinction of parts can be traced, in the mass of ves which spring from it. This distinction becomes more and more obv as development advances; the form and position of the principal or being first marked-out by peculiar aggregations of cells; and the intin structure of each being brought, by progressive metamorphosis of tissues consecutively developed from these, to the type which is cha teristic of it.—Hence we may state the essential character of the func of Generation to consist in the production of a cell of most pecu endowments; which, when supplied with nutriment, and acted-on warmth, does not simply multiply itself so as to produce a mere aggre tion of similar cells, but gives origin to a succession of broods, wh undergo such heterogeneous transformations, as ultimately to evolve organism capable of maintaining an independent existence, in which number of different parts is equal to that of the functions to be p formed, each separate part having an office distinct from that of the re and being specially adapted to it alone.

40. But, it will be inquired, how and where in the Human body (a in the higher Animals in general) is this embryonic vesicle produce and what are the relative offices of the two sexes in its formation? Th is a question which must still be answered with some degree of doub and yet observed phenomena, if explained by the aid of analogy, seem lead to a very direct conclusion. The embryonic vesicle itself, like oth cells, must arise from a germ; and reasons will be hereafter given for th belief, that this germ is the product of the admixture of the contents the 'sperm-cell' of the male with that of the 'germ-cell' of the femal and that this admixture is requisite for the regeneration of that 'germin capacity,' which is gradually expended in the developmental process. Th operations immediately concerned in this function, as in that of Nutritio —namely, the preparation of the 'sperm cells' and of the 'germ-cells,' th act of fecundation, and the development of the embryo, are not dependen upon nervous agency, and are but little influenced by it; and the func tions of Animal Life are called into play, only in the preliminary an concluding steps of the process. In many of the lower Animals, there

tissues by whose instrumentality they are performed. Such move in beings of lowest organisation, probably bear a much greater prop to the whole amount of those exhibited by them, than they do i higher; whilst those which we may regard as specially dependent nervous system, appear to constitute but a small part of their g vital actions. The life of such beings, therefore, bears a much resemblance to that of the Vegetable, than to that of the higher A Their organic functions are performed with scarcely more of se movement, than is seen in plants; and of the motions which they d hibit (nearly all of them *immediately* concerned in the maintenan the organic functions), it is probable that many are the result simple contractility of their tissues, called into action by the st directly applied to them. It is scarcely possible to imagine that beings can enjoy any of those higher mental powers, which Man recog by observation on himself, and of which he discerns the manifest in those tribes, which, from their nearer relation to himself, he regar more elevated in the scale of existence.—If we direct our attentio the other hand, to the *psychical** operations of Man, as forming p his general vital actions, we perceive that the proportion is compl reversed. So far from his Organic life exhibiting a predominan appears entirely subordinate to his Animal functions, and seems dest only to afford the conditions for their performance. If we could ima his nervo-muscular apparatus to be isolated from the remainder o corporeal structure, and to be endowed in itself with the power of m taining its integrity, we should have all that is essential to our id Man. But, as at present constituted, this apparatus is dependent, fo conditions of its functional activity, upon the nutritive apparatus; the whole object of the latter appears to be the supply of those conditi That his mental activity should be thus made dependent upon the supply of his bodily wants, is a part of the general scheme of his bationary existence; and the first excitement of his intellectual pow in a great degree results from the demand thus set up for alimen material.

43. The ministration of the Nervous System to purely Animal obviously consists in part in rendering the mind cognizant of that wh is taking place around, and in enabling it to act upon the material wo by the instruments with which the body is provided for the purpose. is important to observe, that every method at present certainly kno by which Mind can communicate with Mind, involves in the first pl a generation of nervous force, which excites muscular contracti secondly, a physical change determined by that contraction, the medi of which may be sound, light, or motion; and thirdly, the operation this physical change as an 'impression' upon the sensory nerves, through them upon the sensorial ganglia, of the other party. Such is case, for example, not only in that communication which takes place language, whether written or spoken; but in the look, the touch, gesture, which are so frequently more expressive than any words can and thus we see that our interchange of ideas and emotions which

* Here and elsewhere this term will be employed in its most extended sense, to de nate *all* the mental operations, whether intellectual, emotional, or instinctive,— which Man's nervous system is the instrument.

impressions of the same character, a higher amount of force is gi
them.—The apparatus which ministers, however, to the sense of Sm
far less complete in its endowments; for it serves only, in Man at
for the discrimination of odorous emanations, and affords no gui
with regard either to their direction or their source. In fact, the
of information which Man receives through this sense, seems very
akin to that which the lowest animals possessing visual organs
derive from *their* employment. Still a special organ of sense is req
to enable the olfactive nerve to be impressed by the peculiar age
odorous emanations; which, whatever be their nature, have no ope
upon ordinary sensory surfaces.—It is not a little remarkable, tha
speciality of organization of the nerves of Sight, Hearing, and S
renders them incapable of receiving ordinary mechanical impression
that the contact of solid substances with the sensory surfaces which
supply, is not felt, except through the instrumentality of other ne
and no irritation of their trunks, mechanical or otherwise, gives r
feelings of pain. The sense of Taste, however, though special in re
to the peculiarity of the impressions which its organ is adapte
receive, is closely akin to that of Touch in the conditions under whi
is exercised; the absolute contact of the sapid substance with the se
surface being requisite; and the papillary organs in which the gust
nerves may be said to originate, being essentially the same in stru
with those of ordinary tactile surfaces.

45. The Brain and Spinal Cord of Man, in which by far the gr
part of the afferent nerves terminate, and from which nearly all
motor nerves arise, may be considered as made-up of an aggregation
number of distinct ganglionic centres, each of which has its pec
endowments, and is connected with nervous trunks of its own.—C
mencing with the *Spinal Cord*, we find, on comparing it with the ga
ated column of Articulated animals, that it really consists of a seri
ganglia disposed in a longitudinal line, which have coalesced with
other; each ganglion being the centre of the 'nervous circle' prope
one vertebral segment of the trunk. Throughout the entire series
find no other endowment than that of reacting upon an excitant;
excitant being either conveyed by the afferent nerve-trunks, or tr
mitted downwards from the higher parts of the nervous system.
impression which is limited to this series of ganglia, excites any senso
change; so that we may consider the Spinal Cord as the special ins
ment of the 'excito-motor' division of the functions of the nervous
tem. The ordinary Spinal nerves are distributed to the sensory surf
and to the muscular apparatus of the body generally; but at the sum
of the Cord we find a peculiar set of ganglionic centres, included in
part which is distinguished as the *Medulla Oblongata*, whose nerves
distributed to the organs of Respiration, Deglutition, &c., and wh
function consists in sustaining the muscular movements, whose perform
is essential to the continuance of these functions. The movements
question are purely *reflex*; and there is no other reason for distinguish
the endowments of the Medulla Oblongata from those of the Spinal C
save that which arises out of the speciality of the purposes to which
movements are subservient.—At the summit of the Spinal Cord,
partly lodged in the substance of the Medulla Oblongata, we find

kind of association; and thus 'trains of thought' are suggestively evolved, by an operation which (as will be shown hereafter) is not less truly a 'reflex action' of the Cerebrum, than is that which manifests itself directly in producing movement. These trains of thought, whether imaginative or ratiocinative, may proceed quite *automatically*, if left entirely without control; but the Will has a remarkable power of directing them, by concentrating the attention on any subject which it may choose to select from those actually present to the consciousness, and by keeping all others out of view. And when the conclusion of the Intellectual process has been thus arrived-at, the Will can bring its decision to bear upon the muscular system; not, however, as is commonly supposed, by directly transmitting nerve-force to the muscles whose action will be required; but, as will be shown hereafter, by impressing its determinations on the sensori-motor portion of the Nervous system, by whose instrumentality the requisite movements are *instinctively* prompted.*

47. Another division of the Nervous System appears to have for its object, to combine and harmonise certain muscular movements immediately connected with the maintenance of Organic life; and to bring these into relation with certain conditions of the mind. There is further reason to believe that it also influences, and brings into connection with each other, the processes of Nutrition, Secretion, &c., though these, like the muscular movements just mentioned, are essentially independent of it.—This portion of the nervous apparatus is commonly known under the name of the *Sympathetic* system; it has a set of ganglionic centres and nerves of its own; but it is also intimately blended with the Cerebro-spinal system, both receiving fibres from it, and also sending fibres into it.

CHAPTER III.

OF FOOD, AND THE DIGESTIVE PROCESS.

1. *Of Food, its Nature and Destination.*

48. The substances which are required by Animals for the development and maintenance of their fabric, are of two kinds,—the Organic and the Inorganic. The Organic alone are commonly reckoned as

* With reference to that class of operations of which the Cerebrum is the instrument, it is well here to explain, that, though the Physiologist speaks of the Intellectual powers, Moral feelings, &c., as *functions* of the Nervous System, they are not so in the sense in which the term is employed in regard to other operations of the bodily frame. In general, by the *function* of an organ, we understand some change which may be made evident to the senses, as well in our own system, as in the body of another. Sensation, Thought, Emotion, and Volition, however, are changes imperceptible to our senses by any means of observation we at present possess. We are cognizant of them in ourselves, without the intervention of those processes by which we observe material changes external to our minds; but we judge of them in others, only by inferences founded on the actions to which they give rise, when compared with our own. When we speak of sensation, thought, emotion, or volition, therefore, as functions of the Nervous System, we mean only that this system furnishes the conditions under which they exist in the living body; and we leave the question entirely open, whether the Ψυχη has or has not an existence independent of that of the material organism, by which it operates in Man, as he is at present constituted.

Oleaginous matters do not seem to undergo any change preliminar their oxidation, save their reduction to a state of very fine division. shall presently see (§ 54) that a very considerable difference exists betw the Saccharine and the Oleaginous matters, in regard to their rela calorifying powers.—That none of these *non-azotized* substances ca made capable, by metamorphosis or combination within the Animal bo of taking the place of the *azotized* substances as 'histogenetic' or 'plas compounds, may now be regarded as one of the most certain facts Physiology: the concurrent evidence of experiment and observat leading to the conclusion, that in Plants alone can any production azotized compounds take place, and that Animals are in conseque directly or indirectly dependent upon the Vegetable kingdom for th means of subsistence. If animals be fed exclusively upon Saccharine Oleaginous substances, of any kind or in any combination whatever, th speedily perish with symptoms of Inanition: and the only assista which such food affords in the prolongation of life, is derived from calorific power (§ 27).

51. The substances forming the *Albuminous* group are applicable the support of the Animal body, both by affording the materials for t nutrition and re-formation of its tissues, and also by serving (if require for the maintenance of its heat, through the decomposition of which th are susceptible, into hydrocarbonaceous matters adapted for combusti in the lungs, and highly-azotized compounds which pass-off by th kidneys. The proportions of carbon, hydrogen, oxygen, and nitrogen, which all these substances are composed, appear to be identical; and th seem all capable of being reduced by the digestive process to a lik condition. Hence it is a matter of little consequence, except as regar the proportion of inorganic matters with which they may be respective united, whether we draw our histogenetic materials from the flesh animals, from the white of egg (albumen), from the curd of milk (casein from the grain of wheat (gluten), or from the seed of the pea (legumin Neither of these substances, however, can long sustain life when is used by itself; for it has been experimentally ascertained, that by being made to feed constantly on the same substance (boiled white-of egg, for instance, or meat deprived of the osmazome that gives flavour), an animal may be effectually starved; its disgust at such foo being such, that even if this be swallowed, it is not digested.*—The organized fabric of Animals contains also a large quantity of *Gelatin.* It seems certain that this substance may be produced out of fibrin and albumen; since in animals that are supported on these alone, the nutri tion of the gelatinous tissues does not seem to be impaired. But it has been commonly supposed that gelatin taken in as food may serve for the growth and maintenance of these tissues; even though it may be incapable of conversion to the albuminous type. It is very doubtful,

* It is very interesting to remark (with Dr. Prout) that, in the only instance in which Nature has provided a *single* article of food for the support of the animal body, she has mingled articles from the first three of the preceding groups. This is the case in *Milk*; which contains a considerable quantity of an albuminous substance, *casein*, which forms its curd; a good deal of *oily* matter, the butter; and no inconsiderable amount of *sugar*, which is dissolved in the whey. The proportions of these vary in different Mammalia, and they depend in part upon the nature of the food supplied to the Animal that forms the milk; but the substances are thus combined in every instance.

its *histogenetic* value: where, on the other hand, the per-centage of nitrogen is the smallest, that of hydro-carbon is the largest, and the proportion of the combustive material is the highest. The following Table* specifies this proportion in the case of various articles used as food; Human Milk being taken as the standard of comparison, and the quantity of nitrogen it contains being expressed by 100. It must be borne in mind, however, that this substance is intended for the nourishment of a being which passes nearly the whole of its time in a quiescent state, and must not be supposed to be equally well adapted for the sole maintenance of the Human body in a state of activity. In fact, it is inferior in its proportion of Casein (the substance of which alone the azote forms a part) to the milk of other Mammalia, whose young bring their animal functions into exercise at a much earlier period than does the Human infant.—The proportions are those existing in the *dry solids*.

Vegetable.

Rice	81	Barley	125	Brown bread	166
Potatoes	84	Oats	138	Peas	239
Turnips	106	White bread	142	Haricot beans	283
Rye	106	Wheat	119-144	Agaricus deliciosus	289
Maize	100-125	Carrots	150	Beans	320

Animal.

Human milk	100	Salmon, boiled	610	Flounder, boiled	954
Cow's milk	237	Portable soup	764	Pigeon, raw	756
Oyster	305	White of egg	845	—— boiled	827
Yolk of eggs	305	Crab, boiled	859	Lamb, raw	833
Cheese	331-447	Skate, raw	859	Mutton, raw	773
Eel, raw	434	—— boiled	956	—— boiled	852
Mussel, raw	528	Herring, raw	910	Veal, raw	873
Ox liver, raw	570	—— boiled	808	—— boiled	911
Pork-ham, raw	539	Haddock, raw	920	Beef, raw	880
—— boiled	807	—— boiled	816	—— boiled	942
Salmon, raw	776	Flounder, raw	898	Ox lung	931

It is not to be supposed, however, that any table of this kind, founded simply upon the Chemical composition of the various substances, can indicate their respective fitness as articles of diet; since this depends also upon the facility with which they are reduced by the digestive process, and afterwards assimilated. Thus an aliment abounding in nutritive matter, may be inferior to one which really contains a much smaller proportion, if only a part in the first case, and the whole in the second, be readily taken up by the system.

54. The *calorific* powers of the substances above enumerated, however, are not precisely in the inverse ratio to their histogenetic value; for, as the amount of heat given-off in their combustion depends, not simply upon the amount of carbon and hydrogen they may contain, but upon the excess of their hydro-carbon over and above that which is already combined with oxygen, substances that are alike deficient in nitrogen may differ considerably in this respect. Thus in ordinary fat, the proportion of oxygen is only about 10 per cent, whilst that of hydro-carbon is at least 90 per cent; in alcohol, the proportion of oxygen is nearly 35

* Schlossberger and Kemp, in "Philosophical Magazine," Nov. 1845.

thermometer is for many weeks or months in the year at $-40°$ or lower, and where the amount of heat which must be generated within the body is four or five times that for which a diet of bread will suffice.—On the other hand, the general experience of the inhabitants of warm climates seems in favour of a diet chiefly or entirely *vegetable*, and its peculiar suitableness appears to consist in its affording an adequate supply of the plastic alimentary substances, in combination with farinaceous matters that give the requisite *bulk* to the food (§ 104), without affording more combustive material than the system requires,—the quantity of starch which undergoes conversion, and which is introduced as sugar into the circulation, being apparently governed rather by the demands of the respiratory process, than by the amount ingested; the remainder being voided again unchanged.

56. The *mixed* diet, to which the inclination of Man in temperate climates seems usually to lead him (when circumstances allow that inclination to develope itself freely), appears to be fully conformable to the construction of his dental and digestive apparatus, as well as to his instinctive propensities. And whilst on the one hand it may be freely conceded to the advocates of 'Vegetarianism,' that a well-selected vegetable diet is capable of producing (in the greater number of individuals) the highest *physical* development of which they are capable, it may on the other hand be affirmed with equal certainty, that the substitution of a moderate proportion of animal flesh is in no way injurious, whilst, so far as our evidence at present extends, this seems rather to favour the highest *mental* development. If, indeed, we take a comprehensive survey of the conditions of the various races of Man at present inhabiting the earth, we cannot help being struck with his adaptiveness to a great variety of circumstances, as regards climate, mode of life, diet, &c. And we can scarcely avoid the conclusion, that the Creator, by conferring upon him such an adaptiveness, intended to qualify him for subsisting on those articles of diet, whether animal or vegetable, which are most readily attainable in different parts of the globe; and thus to remove the obstacle which a necessary restriction to any one kind of food would have otherwise opposed to his universal diffusion. If we were to bring together the habitual diet-scales of the several races of Men which people the surface of our globe, we apprehend that the diversities which they would present would be scarcely less strange than those which exist among the regimens of the most dissimilar species of Mammalia. We should find the purely animal-feeding on the one hand, the pure vegetarians on the other. Among the former we should find some who devour animal flesh, others fish, and others fowl, while others are even insectivorous; then, again, we should encounter some who devour their food raw, others who cook it; some preferring it immediately that it has ceased to live, while others do not relish it until it has become almost putrescent. So among the vegetable-feeders, we should find some subsisting upon soft fruits, others upon hard grains, others again chiefly upon succulent herbage, and others upon roots so tough as to require artificial means for their reduction. In the various devices by which Man has succeeded in availing himself of these, and in the various tastes which have led some to avail themselves of articles of food which others would loathe, we see the evidence of the same wise Design, as that

II. Experience teaches, however, that it is not a matter of entire indifference, whether the Albuminous constituent be drawn from the Animal or from the Vegetable kingdom, for the use of a highly-animalized diet has a tendency to *raise*, and that of a vegetable diet to *lower*, the proportion of red corpuscles in the Blood (§ 177); whilst, by a due adjustment of the proportion of the two classes of components, the evil effects of the exclusive use of either may be prevented.

III. So, again, Experience teaches what could scarcely have been anticipated theoretically;—namely, that, notwithstanding the power which the living body possesses, of converting saccharine compounds into oleaginous, the ingestion of a certain amount of Oleaginous matter *as such* is necessary, or at least is favourable, to the maintenance of health. We see this provided in large quantity, in the first aliment prepared by nature for the offspring of the Mammalia; and it exists largely in the yolk of the egg of all Oviparous animals. In the ordinary diet of every nation on the globe,—whether this be animal, vegetable, or mixed,—we find one or more articles of an oleaginous nature; and there is a natural craving for such substances when they are completely withheld, which indicates that they serve some important purpose in the economy. Although this craving is so far affected by climate, that it leads to the largest consumption of oily matter where the extreme of cold has to be endured, it exists with no less intensity even in tropical regions, and we find the Hindoo adding his modicum of 'ghee' (or rancid butter) to the rice which constitutes his staple article of diet, with the same relish that the Esquimaux feels for his massive lumps of blubber.—It does not seem difficult to understand the *rationale* of this fact. For whilst the Adipose and Nervous tissues are the only portions of the Animal fabric into which fatty matter enters in any considerable proportion, yet its presence has an important influence on the assimilation of albuminous matters, and seems essential to every act of cytogenesis (see PRINC. OF GEN. PHYS.) We shall hereafter see (§ 135) that it is probably in the Lacteal system, that the two substances are brought into that mutual relation with each other, which these purposes require; and thus it is obvious that, unless a conversion of saccharine into oleaginous matter can take place in the alimentary canal (of which there is no adequate evidence), no true chyle can be formed, except when oleaginous matters have formed part of the food. There is strong and increasing reason to believe, that a deficiency of oleaginous matter, in a state fit for appropriation by the nutritive processes, is a fertile source of diseased action, especially of that of a tuberculous character, and that the habitual use of it in a larger proportion would operate favourably in the prevention of such maladies, as the employment of cod liver-oil unquestionably does in their cure. A most remarkable example of this is presented by the population of Iceland; which, notwithstanding the concurrence of every one of the circumstances usually considered favourable to the scrofulous diathesis, enjoys a most remarkable immunity from it,—without any other assign-

frequent in early autumn, and which are commonly set-down to the account of fruit (although the subjects of them have often abstained entirely from that article), are really the result of the presence of an excess of hydro-carbonaceous matter in the system, consequent upon over-feeding during the summer, and must be looked-upon as the natural means by which it is got rid of.

imperfectly-assimilated histogenetic substances and wrongly-meta phosed products of disintegration, that are not duly eliminated i kidneys; and this diathesis not only displays itself in gout and gr but modifies the course of other diseases. So, again, an excess o *oleaginous* constituents of the food tends to the production of the b diathesis, in which, through the insufficient elimination of hydrocarb ceous matters, the blood becomes charged with the elements of bile. excess of *farinaceous* matters, moreover, especially when combined w deficiency of the albuminous (as it too frequently is among those wh obliged by necessity to live chiefly upon a 'poor' vegetable diet), t to the production of the *rheumatic* diathesis, which seems to consist the arthritic, in the mal-assimilation and wrong metamorphosis of components of the tissues, but to be especially favoured by the pres either of lactic acid, or of some other product of the metamorphos the saccharine compounds. And, as already pointed out, the deficie of oleaginous matters seems to tend to the development of the *scrofu* diathesis; and that of fruits and fresh vegetables to the production of *scorbutic*.*

58. The *absolute quantity* of Food required for the maintenance of Human body in health, varies so much with the age, sex, constitut and habits of the individual, and with the circumstances in which he be placed, that it would be absurd to attempt to fix any standard wh should apply to every particular case. The appetite is the only s guide for the supply of the wants of each; but its indications must be misinterpreted. To eat *when* we are hungry, is an evidently natu disposition; but to eat *as long as* we are hungry, may not always be p dent. Since the feeling of hunger does not depend so much upon state of fulness or emptiness of the stomach, as upon the condition of general system, it appears evident that the ingestion of food cannot *once* produce the effect of dissipating it, though it will do so after a sh time; so that, if we eat with undue rapidity, we may continue swallow food long after we have taken as much as will really be required for wants of the system; and every superfluous particle is not merely usel

* It is worthy of remark that in the times when even the wealthy lived during fou five months of the year almost exclusively upon meat, bread, and flour-puddings, and wh therefore, the diet was far too highly azotized, as well as deficient in fresh vegetab Arthritic, Calculous, and Scorbutic disorders were much more common than at present. T introduction and universal employment of the potato has unquestionably done much correct these two tendencies; on the one hand, by diluting the azotized constituents of food, so that, with the same bulk, a much smaller proportion of these is now introduc and on the other, by supplying to the blood some element which is essential to the ma tenance of its healthy condition. But with the diminution of the arthritic diathesis, wh the experience of our older practitioners, and the medical writings of the last centu indicate as having taken place during that period, there has been an increase in the Rh matic; a change which seems to have a close relation to this alteration in diet. And seems not improbable, too, that this alteration in diet has much to do with that diminish power of sustaining active depletory treatment, which, according to the observation practitioners of long experience, characterizes the present generation as compared with preceding. But whilst there is a diminished capability of bearing large blood-lettin violent purgation, &c., there is at the same time such an increased tendency to a favoura termination in many of those diseases for which they were formerly accounted necessa as should remove all regret at this change of constitution. On the question of 'Vege rianism,' the Author may refer to his articles on that subject in the "Brit. and For. Me Chir. Rev.," vol. vi. pp. 76 and 399.

however, is sometimes done erroneously; thus 8 oz. of fresh vegeta which contain only 1½ oz. of solid nutriment, are exchanged for 12 o flour, which is almost all nutritious. Sugar and Cocoa are also allo partly in exchange for a portion of the Spirits formerly served ou further diminution of which has recently been effected, with great ben —A considerable reduction in this amount is of course admissible, w little bodily exertion is required, and where there is less exposure to temperatures. In the case of Prisoners, the diet should of course b spare as possible, consistently with health; but it should be caref modified, in individual cases, according to several collateral circumstan such as depression of mind, compulsory labour, previous intempe habits, and especially the length of confinement. It has been suppo by some, that prisoners require a fuller diet than persons at large; t is probably erroneous; but more variety is certainly desirable, to co teract, as far as possible, the depressing influence of their condition u the digestive powers. The evil effect of an undue reduction in t supply of food, and of insufficient attention to its quality, has un tunately been too frequently displayed in our prisons; a notable exam of which will be hereafter alluded-to (§ 73). A very excellent scale dietaries adapted to the different conditions of Prison-life, has been iss by the Government on the recommendation of the Inspector of priso —The effects of confinement have been well shown in the experience the Edinburgh House of Refuge, which was first established in 1832, the reception of beggars during the Cholera, and which has been contin to the present time. The diet was at first a quart of oatmeal porrid for each person, morning and evening; and at dinner 1 oz. of meat, broth, with 7 oz of bread, making altogether about 23 oz. of solid fo per day. During some months, this diet seemed to answer very wel the people went out fatter than they came in, owing to the diet bei better than that to which they had been accustomed; but afterwards proneness to disease manifested itself in those who had been resident there for a considerable time, and the diet was therefore somewhat i creased with good effect. The quantity of animal food was probabl here too small; and the total weight might still have been sufficient, it had been differently apportioned.—The inmates of Workhouses, espe cially those who have been accustomed to poor food during their whol lives, require much less than those more actively employed; and it is o importance that the diet should not be superior in quantity or quality, t that which the labouring classes in the respective neighbourhoods pro vide for themselves. A series of Diet-scales for Paupers has been issue by the Poor Law Commissioners, who state that these have all bee employed in different parts of England, and have been found to wor well; the average daily amount of solid aliment in these is only 25½ oz. and of this, not above 18 oz. would be *dry* nutriment.* In the Edinburgh workhouse, of which the inmates usually have good health, they are fe upon oatmeal-porridge morning and evening, with barley-broth at dinner; the total allowance of dry nutriment is about 17 oz.; namely 13 oz. o vegetable, and 4 oz. of animal. In the Irish Poor-houses, notwithstanding the sufficiency of the diet-scales, which are more liberal than that las

* A copious collection of Dietaries will be found in Dr. Pereira's "Treatise on Food an Diet," and in Dr. Robertson's "Treatise on Diet and Regimen."

and firmness of the muscles, clearness of the skin, capability of be continued severe exercise, and a feeling of freedom and lightne 'corkiness') in the limbs. During the continuance of the system, found that the body recovers with wonderful facility from the effe injuries, wounds heal very rapidly, cutaneous eruptions usually d pear. Clearness and vigour of mind, also, are stated to be results of plan.*

62. It is not enough for the healthy support of the body, that Food ingested should contain an adequate proportion of alimentary stituents; it is important that these should be in a wholesome or un composing state. Putting out of view all impregnations with deleter substances, which the articles used as food may have received f various external sources, it cannot be questioned that they may deri poisonous character from changes taking place in their own composi Thus it is a fact very familiar to German Toxicologists, that cheese, ba sausages, and other articles, may spontaneously undergo such deleter alterations, as give rise, when they are employed as food, to all symptoms of irritant poisoning, which may even pass on to produce f consequences; that such occurrences are very rare in this country probably to be attributed to a difference in the mode of preparati This change does not appear to consist in simple putrescence; for effects which the cheese-poison, sausage-poison, &c., produce on the ani economy, are far more potent than mere putrescence could occasion; it is supposed by Liebig to consist in the generation of a peculiar ferme which the stomach is not able to decompose. Similar changes in ordin flesh-meat seem to be sometimes consequent upon the previous existe of a diseased condition in the animal which furnished it. Many insta of this kind have been recorded,† and the risk is quite sufficient justify a strict prohibition of the use of any such article.—That m which is simply putrescent is to be considered as injurious *per se*, wh habitually employed, is scarcely a matter of reasonable doubt. It is t that some nations are in the habit of keeping their meat until it is taint having a preference for it in that condition, which seems to have grow out of the supposed necessity for thus employing it; a preference whi has its parallel among the epicures in our own country, who consider t *haut goût* essential to the perfection of their venison or woodcock. O of the most remarkable examples of this kind among a civilized people furnished by the inhabitants of the Faroe islands, who, according to t Report of Dr. Panum, who has investigated their Sanitary condition, li

* The method of training employed by Jackson (a celebrated trainer of prize-fighters in modern times), as deduced from his answers to questions put to him by John Bell, was begin on a clear foundation by an emetic and two or three purges. Beef and mutton, lean of fat meat being preferred, constituted the principal food; veal, lamb, and pork w said to be less digestible ("the last purges some men"). Fish was said to be a "wat kind of diet," and is employed by jockeys who wish to reduce weight by sweating. St bread was the only vegetable food allowed. The quantity of fluid permitted was 3½ pi *per diem*, but fermented liquors were strictly forbidden. Two full meals, with a lig supper, were usually taken. The quantity of exercise employed was very considerable, a such as few men of ordinary strength could endure. This account corresponds very mu with that which Hunter gave of the North American Indians, when about to set-forth o long march.

† See "Ann. d'Hygiene," 1829, ii., p. 267; 1834, ii., 69; also Taylor in "Gu Hospital Reports," April, 1843.

63. That it is Water which constitutes the natural drink of Man, that no other liquid can supply its place, is apparent from the cursory glance at its uses in the system; and it is only necessary he remark, that the purity of the water habitually ingested is a poi extreme importance. A very minute impregnation with lead, fo ample, is quite sufficient to develope all the symptoms of chronic poisoning, if the use of such water be sufficiently prolonged. In the of the ex-royal family of France, many of whom suffered in this ma at Claremont,* the amount of lead was only about one grain per gal and in a case subsequently published, in which also the symptom lead-poisoning were unequivocally developed, the amount was no than 1-9th of a grain.† So, again, an excess of the saline ingredi which appear to be innocuous in small quantities, may produce a ma disorder of the digestive organs, and (through them) of the sy generally.‡ Moreover, as in the case of food, the presence of a small amount of putrescent matter is quite sufficient to produce most pernicious results, when that matter is habitually introduced the system; and these results, on the one hand, manifest thems in the production of certain disorders which appear distinctly trace to the direct action of the poison so introduced, whilst, on the o they become apparent in the extraordinary augmentation of the liab to attacks of such zymotic diseases as may at the time be prevalent.§

following night, all who had eaten of the oysters (so far as Dr. Brittan could asce were attacked with cholera and choleraic diarrhœa, and eleven of the children die next day.

* See the account of this case, which presents many features of great interest, in "Dublin Quarterly Journal of Medical Science," vol. vii. p. 415.

† See Herapath in "Medical Gazette," Sept. 20, 1850, p. 518.

‡ Of this a very instructive case, which occurred at Wolverton, has been published Mr. Corfe in the "Pharmaceutical Journal," July, 1848. So large a number of viduals were there attacked, after the use of water from a certain well for some mo with disorders bearing a strong general resemblance to each other, though differing in subordinate features, and the intensity of these disorders bore such a constant ratio t amount of the saline water habitually employed, that no reasonable doubt could with respect to its causative agency. Yet the total quantity of saline matter was about 40 grains per gallon, or but little more than one-sixth of that which is contai the Marienbad water, the spa to which it presented the greatest resemblance in the bination of its components; and as the symptoms which were prevalent at Wolverton a very close correspondence with those which are known to result from the imprudent of the Marienbad water, it appears that here too the same effects are produced by the l continued employment of the weaker beverage, as by a much smaller number of dos the stronger one.

§ For ample evidence to this effect, see Dr. Pereira's "Treatise on Food and Di pp. 89-91; and the "Report of the General Board of Health on the Epidemic Ch 1848 and 1849," pp. 59-63, "Appendix A," p. 14, and "Appendix B," pp. 91-95. — following very instructive case occurred a few years ago, within the Author's own kn ledge. In a certain terrace, in the most aristocratic suburb of a large provincial to consisting of houses of a superior class, and very favourably situated as regards access of pure air, an epidemic of gastric fever broke-out, much to the astonishm and dismay of the residents, no such malady having ever been known to prevail the neighbourhood. It was soon observed, however, that the attacks of the fever w limited (in the first instance at least) to those individuals who were accustomed to use water of a neighbouring well; those who were supplied from a deep spring at a dista being entirely free. For some little time before this outbreak, a disagreeable taste been observed in the well water, and this was subsequently traced to the bursting o sewer, which had discharged part of its contents into the well. This cause being remov the terrace has since exhibited no tendency whatever to a recurrence of the effect.

they are universally admitted to possess a *poisonous* character, w administered in large doses, death being the speedy result, through suspension of nervous power, which their introduction into the circ tion in sufficient quantity is certain to induce. *Secondly*, when h tually used in excessive quantities, universal experience shows Alcoholic liquors tend to produce a morbid condition of the body large, and especially of the nervous system; this condition being such a knowledge of its *modus operandi* on the body would lead the Physi gist to predicate.—*Thirdly*, the frequent occurrence of more chro diseases of the same character, among persons advanced in life, who h habitually made use of Alcoholic liquors in 'moderate' amount, affor strong probability that they result from a gradual perversion of nutritive processes, of which that habit is the cause. This perver manifests itself peculiarly in the tendency to 'fatty degeneration' of muscular substance of the heart, of the walls of the arteries, of glandular substance of the kidney and liver, and of many other pa and thus gives rise to a great variety of forms of disease. It se probable that its *modus operandi* in these cases, is not so much by direc deteriorating the formative operations, as by obstructing the removal the hydrocarbonaceous products of the continual disintegration of tissues, in virtue of the stronger affinity which alcohol has for oxyg whereby it will prevent the Respiratory process from exerting its influence in the purification of the blood.—*Fourthly*, the special habil of the intemperate to zymotic diseases, seems an indication that the ha tual ingestion of Alcoholic liquors tends to prevent the due eliminat of the azotized products of the disintegration of the system, and thus induce a 'fermentible' condition of the blood (§ 226).—*Fifthly*, extend experience has shown, that notwithstanding the temporary augment tion of power which may result from the occasional use of ferment liquors, the capacity for prolonged endurance of mental or bodily labo and for resisting the extremes of heat and cold, as well as other d pressing agencies, is diminished rather than increased by their habitu employment.—On these grounds, the Author has felt himself fu justified in the conclusion, that, for Physiological reasons alone, habitu abstinence from Alcoholic liquors is the best rule that can be la down for the great majority of healthy individuals; the exceptio cases in which any real benefit can be derived from their use, bei extremely few.*

2. *Of Hunger and Thirst;—Starvation.*

66. The want of solid aliment, arising out of the several sources demand formerly enumerated (§§ 26-28), is indicated by the sensation Hunger; and that of liquid, by Thirst. The former of these sensatio is referred to the stomach, and the latter to the fauces; but althou certain conditions of these parts may be the immediate cause of t sensations in question, they are really indicative of the requirements the system at large. For the intensity of the feeling bears no consta relation to the amount of solid or liquid aliment in the stomach; whil

* See his "Physiology of Temperance and Total Abstinence;" also the important Tre tise on "Alcoholismus Chronicus" by Dr. Huss of Stockholm, of which an abstract is giv in the "Brit. and For. Med.-Chir. Rev.," vols. vii. and ix.

excited; the capillary vessels are gradually unloaded; and the immed cause of the impression on the nervous system is withdrawn.* By conversion of the alimentary matter into materials fit for the nutr of the system, the remote demand also is satisfied; and thus it is, the condition of the stomach just referred-to, is permanently reli by the ingestion of substances that can serve as food. But if ingested matter be not of a kind capable of solution and assimila or the digestive apparatus cannot effect its preparation, the feelin hunger is only temporarily relieved, and soon returns in greater than before.—The theory here given seems reconcilable with all has been said of the conditions of the sense of Hunger; and part larly with what is known of the effect produced upon it by nerv impressions, which have a peculiar influence upon the capillary circ tion. It also corresponds exactly with what we know of the influe of the nervous system, and of mental impressions, upon other secreti (CHAP. XV.).

68 The sense of Hunger, like other sensations, may not be taken c nizance of by the Mind, if its attention be strongly directed towa other objects; of this fact, almost every one engaged in active ope tions, whether mental or bodily, is occasionally conscious. The noctur student, who takes a light and early evening meal, and, after devot himself to his pursuits for several hours uninterruptedly, retires to r with a wearied head and an empty stomach, but without the least sen tion of hunger, is frequently prevented from sleeping by an indescrib feeling of restlessness and *deficiency;* and the introduction of a sm quantity of food into the stomach will almost instantaneously allay th and procure comfortable rest. Many persons, again, who desire to ta active exercise before breakfast, are prevented from doing so by the las tude and even faintness which it induces,—the bodily exercise increasi the demand for food, whilst it draws-off the attention from the sensati of hunger.†

69. The conditions of the sense of Thirst appear to be very analogo

* These views seem to be confirmed by the observations of M. Bernard on the condit of the gastric follicles during the intervals of their functional activity (§ 94).

† The Author may be excused for mentioning the following circumstance, which so years ago occurred to himself, and which seems to him a good illustration of the princip that the sense of hunger *originates* in the condition of the general system, and that i *manifestation*, through a peculiar action in the stomach, is to be regarded as a second phenomenon adapted, under ordinary circumstances, to arouse the mind to the actio necessary for the supply of the physical wants, but capable of being overlooked, if t attention of the mind be otherwise directed. He was walking alone through a beauti country, and with much to occupy his mind; and, having expected to meet with so opportunity of obtaining refreshment on his road, he had taken no food since his brea fast. This expectation, however, was not fulfilled; but, as he felt no hunger, he thoug little of the disappointment. It was evening before he approached the place of h destination, after having walked about twenty miles, resting frequently by the way and he then began to feel a peculiar lassitude, different from ordinary fatigue, whic rapidly increased, so that during the last mile he could scarcely support himself. Th "stimulus of necessity," however, kept him up; but on arriving at his temporary hom he immediately fainted. It is obvious that, in this case, the occupation of the min on the objects around, and on its own thoughts, had prevented the usual warning o hunger from being perceived; and the effect which succeeded was exactly what was to b anticipated, from the exhaustion of the supply of food occasioned by the active and pro longed exertion.

animal, and include much saline matter in addition to the biliary. The average loss of weight in the warm blooded animals experimented on by M. Chossat, between the commencement of the period of Inanition and its termination by death, was 40 per cent: but he met with considerable variation in the extremes, which seemed to depend chiefly on the amount of fat previously accumulated in the body; those animals losing most weight, in which the fat had been most abundant, which were also those that lived the longest.* Taking 40 per cent as the mean, M. Chossat obtained the following curious results, as regards the relative diminution of the several tissues and organs of the body; those which lost *more* than the mean, being distinguished from those which lost *less*.

Parts which lose *more* than 40 per cent.		Parts which lose *less* than 40 per cent.	
Fat	93·3	Muscular coat of stomach	39[illegible]
Blood	75 0	Pharynx and œsophagus	34[illegible]
Spleen	71·4	Skin	33[illegible]
Pancreas	64 1	Kidneys	31[illegible]
Liver	52·0	Respiratory apparatus	22[illegible]
Heart	44 8	Osseous system	16[illegible]
Intestines	42 4	Eyes	10[illegible]
Muscles of Locomotion	42 3	Nervous system	1[illegible]

The points most worthy of note in the above table, are the almost complete removal of the *fat*, and the reduction of the *blood* to three-fourths its normal amount; whilst the *nervous system* undergoes scarcely any loss. It would seem, in fact, as if the supervention of death was coincident with the consumption of all the disposable combustive material; and that up to that point, the whole remaining energy of nutrition is concentrated upon the nervous system. And it will be shown hereafter (CHAP. X Sect. 2), that there is adequate ground for considering death by *starvation* as really death by *cold;* since the temperature of the body is maintained with little diminution until the fat is thus consumed, and then rapidly fails, unless it be kept-up by heat externally applied. As might be expected from the comparative rapidity of interstitial change at the earlier periods of life (CHAP. XVIII), it was found by Chossat that the diurnal loss was much the most rapid in young animals, and that the duration of their lives when deprived of food was consequently far less than that of adults. He further ascertained that the results of *insufficient* alimentation were in the end the same as those of entire deprivation of food, the total amount of loss being almost exactly identical, but its rate being less, so that a longer time was required to produce it. He did not find that much influence was exerted on the duration of life, by permitting or withdrawing the supply of water; but this statement does not apply to Man, in whom death supervenes much earlier when liquid as well as solid aliment is withheld, and the indifference in the case of

* There is a well known case of a fat pig, which was buried in its sty for 160 days, under thirty feet of the chalk of Dover cliff, and which was dug out alive at the end of that time, reduced in weight from 160 lbs. to 40 lbs., or no less than 75 per cent. ("Trans. of Linn Soc," vol xi p 411). The extraordinary prolongation of life in this case may be attributed to the retention of the *heat* of the body by the non-conducting power of the chalk, and to the retention of its *moisture* by the saturation of the air in its immediate vicinity

pestilential diseases most certainly follow in the wake of a famine, carry off a far greater number than perish from actual starvation.

73. Another class of phenomena, however, results from such a ciency of alimentation as is not adequate to produce the results ju scribed; provided this deficiency be prolonged for a considerable len time, and especially if it be conjoined with other unfavourable condi Of this, a remarkable example was presented at the Milbank Penite in 1823. The prisoners confined in this establishment, who had viously received an allowance of from 31 to 33 oz. of dry nutri daily, had this allowance suddenly reduced to 21 oz., animal food b almost entirely excluded from the diet scale. They were at the same subjected to a low grade of temperature, and to considerable exer and were confined within the walls of a prison situated in the midst marsh which is below the level of the adjoining river. The prison been previously considered healthy; but in the course of a few mo the health of a large proportion of the inmates began to give way. first symptoms were loss of colour, and diminution of flesh and stren subsequently diarrhœa, dysentery, and scurvy; and lastly adynamic fe or headache, vertigo, convulsions, maniacal delirium, apoplexy, &c. smallest loss of blood produced syncope, which was frequently fatal: after death, ulceration of the mucous lining of the alimentary canal very commonly found. Out of 860 prisoners, no fewer than 437, o per cent, were thus affected. The influence of concurrent conditi especially of previous confinement, was here remarkably shown; for t were found to be most liable to disease, who had been in prison the l est. That the reduction of the allowance of food, however, was the source of the epidemic, was proved by the two following facts — prisoners employed in the kitchen, who had 8 oz. of bread additional day, were not attacked, except three who had only been there a few d and after the epidemic had spread to a great extent, it was found that addition of 8 oz. to the daily allowance of vegetable food, and ½ oz. to animal, greatly facilitated the operation of the remedies which were u for the restoration of health.*—Another very striking example of effects of prolonged insufficiency of diet, has been furnished by 'Maison Centrale' of Nîmes, which is a large Penitentiary contai an average of 1200 prisoners. The mortality in this prison, between years 1829 and 1847, varied from 1 in 7·85 to 1 in 23·88, the aver being 1 in 12·70; whilst the average mortality among the inhabitant the town of Nîmes, of the same age and sex, was only 1 in 49·9; so t the mortality among the prisoners was from *two* to *six* times as grea that among the townspeople, the average being nearly *four* times. Seve causes doubtless concurred to produce this terrible result; but wh over-crowding and deficient ventilation were *constant*, deficiency of fo amount of labour exacted, and depression of temperature were *varia* and the variations in the amount of mortality followed these last so u formly, that there could be no doubt of their dependence upon them.†

74. It is a curious effect of insufficient nutriment, as shown by

* See Dr. Latham "On the Diseases in the Milbank Penitentiary;" 1824

† See the highly instructive account of this series of occurrences, by M. Boil Castelnau, chief physician to the 'Maison Centrale,' in "Ann. d'Hygiène Pub Janv., 1849

damp vault, in which they had been buried under a ruin. Dr. Sloa given an account* of the case of a healthy man æt. 65, who was f alive after having been shut-up in a coal-mine for twenty-three during the first ten of which he was able to procure and swallow a quantity of foul water; he was in a state of extreme exhaustion, and three days afterwards, notwithstanding the attempts made to recover —It would seem as if certain conditions of the Nervous system, espe those attended with peculiar emotional excitement, are favourable to prolongation of life under such circumstances. Thus, in a case reco by Dr Willan, of a young gentleman who starved himself under the i ence of a religious delusion, life was prolonged for 60 days; during whole of which time, nothing else was taken than a little orange j In a somewhat similar case which occurred under the Author's notic the person of a young French lady, more than 15 days elapsed betw the time that she ceased to eat regularly, and the time of her being c pelled to receive nourishment; during this period she took a good de exercise, and her strength seemed to suffer but little, although she s lowed solid food only once, and then in small quantity. Again, in cer states of the system commonly known as 'hysterical,' there is freque a very remarkable disposition for abstinence, and power of sustaining In a case of this kind which occurred under the Author's own obser tion, a young lady, who had just before suffered severely from the te form of Hysteria, was unable to take food for three weeks. The slight attempt to introduce a morsel of solid matter into the stomach, oc sioned violent efforts at vomiting, and the only nourishment taken dur the period mentioned, was a cup of tea once or twice a day, and on m days not even this was swallowed. Yet the strength of the patient rat increased than diminished during this period; her muscles became firm and her voice more powerful.—It may be well to remark that, under su circumstances, the continual persuasions of anxious friends are very inj rious to the patient; whose return to her usual state will probably ta place the earlier, the more completely she is left to herself.

3. *Movements of the Alimentary Canal.*

77. The motions by which Food is conveyed to the *Mouth* and intr duced into its cavity, constituting the acts of *Prehension* and *Ingestio* are ordinarily considered to be *voluntary*, at least in the adult; and it indubitable that the Will has entire control over them. Neverthele they belong to that class of 'secondarily automatic' movements, who character has been already noticed (§ 45), and like the movements locomotion, may be kept-up when the will is in abeyance, by the su gesting and guiding influence of sensations, thus being performed und the same essential conditions as the purely 'consensual' or 'sensori-moto actions.† The necessity of 'guiding sensations' for their performance

* "Medical Gazette," vol. xvii. p. 389.

† This, the Author thinks, will be conformable to the experience of most of his reader who will find, if they analyze their own consciousness, that they continue to eat wh their whole *attention* is given to some abstract train of thought, or to some external obje But a remarkable case will be cited hereafter (CHAP. XI., Sect. 6), which fully confir the view here advanced; the movements, not merely of the lips and jaws, but those which food was conveyed to the mouth, having been carried on *automatically*, when on (so to speak) the spring was touched by which they were set in action.

most advantageous form to a digestive menstruum. The complete disintegration of the alimentary matter is, therefore, of great consequence; and, if imperfectly effected, the subsequent processes are liable to derangement. Such derangement we continually meet with; for there is not, perhaps, a more frequent source of Dyspepsia than imperfect mastication, whether resulting from the haste with which the food is swallowed, or from the want of the instruments proper for the reducing operation. The mechanical disintegration of the food is manifestly aided by Insalivation; but the admixture of Saliva also exerts, as we shall hereafter see (§ 93), a very marked influence on the chemical composition of certain of its constituents.—The movements of Mastication, still more than those already adverted-to, although under the complete control of the Will, and originally dependent upon it for their excitation, come at last to be of so *habitual* a character, that they continue when the direct influence of the will is withdrawn, the influence of the 'guiding sensation,' however, being essential to their performance.* Every one is conscious that the act of mastication may be performed as well, when the mind is attentively dwelling on some other object, as when directed to *it*; but, in the former case, we are rather apt to go on chewing and rechewing what is already fit to be swallowed, simply because the will does not exert itself to check the action, and to carry the food backwards within the reach of the muscles of deglutition. This conveyance of food backwards to the fauces is a distinctly voluntary act; and it is necessary that it should be guided by the sensation, which there results from the contact it induces. If the surface of the pharynx were as destitute of sensation, as is the lower part of the œsophagus, we should not know when we had done what was necessary to excite its muscles to operation.—The muscles concerned in the Mastication of food are nearly all supplied by the third branch of the Fifth pair, a large proportion of which is well known to have a motor character. Many of these muscles, especially those of the cheeks, are also supplied by the Facial nerve; and yet, if the former be paralyzed, the latter cannot stimulate them to the necessary combined actions. Hence we see that the movements are of an associated character, their due performance being dependent on the part of the nervous centres, from which the motor influence originates.† If the Fifth pair, on the

* Thus, in the curious case formerly referred-to (p. 19, *note*), food can only be administered by carrying-back the spoon containing it, until it touches the fauces and thus excites an act of deglutition. Sensation being here entirely deficient, there is nothing to excite or to guide the movements of the muscles of the mouth and tongue.

† Comparative Anatomy furnishes the key to these phenomena, which seem at first sight to be somewhat strange. Among Invertebrate animals generally, the Respiratory organs are completely unconnected with the mouth; and a very distinct set of muscles is provided to keep them in action. These muscles have separate ganglia as the centres of their operations; and these ganglia are only connected indirectly with those of the sensori-motor system. The same is the case, in regard to the introduction of the food into the digestive apparatus. The muscles concerned in this operation have their own centres, —the Stomato-gastric and Pharyngeal ganglia,—which are not very closely connected either with the cephalic, or with the respiratory, or with those of general locomotion. Now in the Vertebrata, the distinct organs have been so far blended together, that the same muscles serve the purposes of both; but the different sets of movements of these muscles are excited by different nerves; and the effect of division of either nerve, is to throw the muscle out of connection with the function to which that nerve previously rendered it subservient,—as much as if the muscle were separated from the nervous system altogether.

80. The purely *automatic* nature of the act of Deglutition is shown by the fact, that no attempt on our own part will succeed in performing it really *voluntarily*. In order to excite it, we must apply some stimulus to the fauces. A very small particle of solid matter, or a little fluid (saliva, for instance), or the contact of the back of the tongue itself, will be sufficient; but without either of these, *we cannot swallow at will.* Nor can we restrain the tendency, when it is thus excited by a stimulus; every one knows how irresistible it is, when the fauces are touched in any unusual manner; and it is equally beyond the direct control of the will, in the ordinary process of eating,—voluntary as we commonly regard this. Moreover, this action is performed, like that of respiration, when the power of the will is suspended, as in profound sleep, or in apoplexy affecting only the brain; and it does not seem to be at all affected by the entire removal of the brain, in an animal that can sustain the shock of the operation; being readily excitable, on stimulating the fauces, so long as the nervous structure retains its functions. This has been experimentally proved by Dr M. Hall; and it harmonizes with the natural experiment sometimes brought under our notice in the case of an anencephalous infant, in which the power of swallowing seems as vigorous as in the perfect one. But, if the 'nervous circle' be destroyed, either by division of the trunks, or by injury of any kind to the portion of the nervous centres connected with them, the action can no longer be performed; and thus we see that, when the effects of apoplexy are extending themselves from the brain to the spinal cord, whilst the respiration becomes stertorous, the power of Deglutition is lost, and then respiration also speedily ceases.

81. Our knowledge of the nerves specially concerned in this action, is principally due to the very careful and well-conducted experiments of Dr. J Reid.*—The distribution of the Glosso-pharyngeal evidently points it out as in some way connected with it; but this, when carefully examined, discloses the important fact, that the nerve scarcely sends any of its branches to the muscles which they enter, these mostly passing through them, to be distributed to the superjacent *mucous surface* of the tongue and fauces. Further, when the trunk is separated from the nervous centres, irritation produces scarcely any muscular movements. Hence it is not in any great degree an 'efferent' or motor nerve; and its distribution would lead us to suppose its chief functions to be 'afferent,' namely, the conveyance of impressions from the surface of the fauces to the Medulla Oblongata. This inference is fully confirmed by the fact, that, so long as its trunk is in connection with the centre, and the other parts are uninjured, pinching, or other severe irritation of the Glosso-pharyngeal, will often excite distinct acts of deglutition. Such irritation, however, may excite only convulsive twitches, instead of the regular movements of swallowing; and it is evident that, here as elsewhere, the impressions made upon the extremities of the nerves are much more powerful excitors of reflex movement, than are those made upon the trunk, though the latter are more productive of pain. It was further observed by Dr. Reid, that this effect was produced by pinching the pharyngeal branches only; no irritation of the lingual division being effectual to the purpose.—If, then,

* "Edinb. Med and Surg Journ," vol xlix.; and "Physiological, Anatomical, and Pathological Researches," CHAP IV

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84. With regard to the degree in which these movements of Stomach, whose share in the Digestive operation is so important, are pendent upon the Spinal cord, and are consequently of a 'reflex' na it is difficult to speak with certainty, owing to the contradictory re obtained by different experimenters. These contradictions, however, partly due to a diversity in the nature of the animals experimented and partly to a difference in the stage of the digestive process at w the observations were made. It seems to be well established by researches of Reid, Valentin, and others,* that distinct movements be excited in the stomach of the Rabbit, if distended with food, by irr ing the Pneumogastric soon after the death of the animal; these m ments appear to commence from the cardiac orifice, and then to sp themselves in a sort of peristaltic manner along the walls of the stom but no such movements can be excited if the stomach be empty. Var experiments upon living animals have led to a similar conclusion, taken-in shortly before or subsequently-to its division, having been fo to be only dissolved on the surface of the mass, where it was in con with the mucous membrane: but these experiments have been m for the most part upon Herbivorous animals, such as horses, asses, rabbits, whose food is bulky and difficult of solution, requiring to constantly changed in its position, so that every part of it may be suc sively brought to the exterior. On the other hand, Dr Reid found, in experiments upon Dogs, that, after the first shock of the operation gone-off, solution of food in the stomach, and absorption of chyle mi take place; and hence it may be inferred, that no influence of this ne upon the muscular parietes of the stomach is essential to digestion in t species. This conclusion harmonises well, therefore, with the fact alre stated respecting the absence of such influence in the lower parts of œsophagus; and it may, perhaps, be explained by the consideration, t the natural food of the dog is much less bulky and more easy of soluti than that of the animals previously named, so that there is not so m need of that peculiar movement, which is in them so important an aid the process of reduction.—There is yet much to be learned on this s ject, however; especially in regard to the degree in which the moveme may be checked or altered, by impressions transmitted through the nerv system. It was stated by Brachet,† that, in some of his experiments u the Pneumogastric, some hours after section of the nerve on both sid the surface only of the alimentary mass was found to have underg solution, the remainder of the mass remaining in the condition in wh it was at first ingested; and if this statement can be relied-on, it wo appear that the movements of the stomach, like those of the heart, can readily affected by a strong nervous impression. It may be partly in t manner, therefore, and not by acting upon the secretions alone, th strong Emotions retard or even check the digestive process, as they well known to do. On the other hand, the moderate excitement pleasurable emotions may be favourable to the operation; not only giving firmness and regularity to the action of the heart, and ther

* See Dr Reid's "Physiological, Anatomical and Pathological Researches," chap. Valentin "De Functionibus Nervorum Cerebralium," &c. chap. xi.; also Longet "An et Physiol du Système Nerveux," tom. i p 323, and Bischoff in "Müller's Archiv.," 18

† "Rech Exper sur les Fonct. du Syst. Nerv. Ganglion," chap. iii. § 2.

the vomiting which is consequent upon the strangulation of a hernia the passage of a renal calculus; or in that which is excited by the in tion of tartar-emetic or emetin into the circulating current, where t substances probably produce their characteristic effect by their opera on the nervous centres. 3rd. Impressions received through the *sensa* centres, which may be either sensational or emotional, but which do operate unless they are *felt*. In this mode seems to be excited the vo ing that is induced by tickling the fauces, which first gives rise to sensation of nausea; as well as the vomiting consequent upon disgus sights, odours, or tastes, and upon those peculiar internal sensations wh are preliminary to 'sea-sickness.' The *recollection* of these sensati conjoined with the emotional state which they originally excited, itself become an efficient cause of the action, at least in individual peculiarly irritable stomachs or of highly sensitive nervous systems; this plays downwards upon the sensorial centres, in such a manner as excite in them the same condition, as that which was originally produ through the medium of the sensory nerve, when the object was actu present. (See CHAP. XI., Sect. 3.)

86. The passage of the Chyme, or product of the gastric digest through the pyloric orifice, into the commencement of the *Intestinal* is at first slow, but when the digestive process is nearly completed, i transmitted in much larger quantities. The pyloric orifice, like cardiac, is furnished with a sphincter muscle, but how far its contracti are dependent upon 'reflex action,' has not yet been ascertained. T ingested matter, which undergoes further changes of a very import character within this portion of the canal, is gradually propelled onwa by the peristaltic contractions of its walls; and these are excited by contact, either of the products of digestion, or of the secretions poure by the various glands that discharge their products into the intesti tube.* In its progress along the small intestines, the nutritious port of the ingested matter is gradually taken-up by the blood vessels a absorbents; and the residue, combined with excrementitious matt separated from the blood, begins to assume the fæcal character. A furt absorption takes place during the passage of the fæcal matter throu the large intestines; and thus by the time it reaches the rectum, it acquired a considerable degree of consistency.—The ordinary Peristal movements of the Intestinal canal are fully accounted for, by referri them to the contractility of the muscular portion of its walls, called in action by direct stimulation; and that they are not in any degree depe dent upon nervous connection with the Cerebro-spinal centres, is clea shown by their continuance after the destruction of these. Some Phy ologists suppose that these movements are attributable to 'reflex' actio through a nervous circle furnished by the fibres and ganglia of t Sympathetic system. This supposition, however, is entirely unnecessar since the Hallerian doctrine of the independent irritability of Muscle, a truth which may now be considered as firmly established (See PRINC. GEN. PHYS.), affords an adequate explanation of them. And it will

* The Bile seems to have an important share in producing this effect; since, when t ductus choledochus is tied, constipation always occurs. The purgative action of Mercuri seems to depend in great part upon the increase of the hepatic and other secretions whi it induces.

either for its contractility, or for its power of exercising it, but is enabled to propel its contents by its own inherent powers. still we find that here, as in other instances, the nervous centres exert a general control over even the Organic functions, doubtless for the purpose of harmonizing them with each other, and with the conditions of the organs of Animal life. (See CHAP XIII., Sect. 4.)

88. On examining the outlet by which the fæces are voided, we find that it is placed, like the entrance, under the guardianship of the Spinal Cord; subject, however, to some control on the part of the Will. In the lowest animals, the act of discharging excrementitious matter is probably as involuntary as are the acts immediately concerned in the introduction of nutriment; and it is performed as often as there is anything to be got rid of. In the higher classes, however, such discharges are much less frequent; and reservoirs are provided, in which the excrementitious matter may accumulate in the intervals. The associated movements required to empty these, are completely involuntary in their character; and are excited by the quantity, or stimulating quality, of the contents of the reservoir. But, had volition no control over them, great inconvenience would ensue; hence sensation is excited by the same stimulus which produces the movements, in order that, by arousing the will, the otherwise involuntary motions may be restrained and directed.—There can be little doubt, from the experiments of Dr. M. Hall, as well as from other considerations, that the associated movements by which the contents of the rectum and bladder are discharged, correspond much with those of Respiration; being in their own nature excito-motor, but being capable of a certain degree of voluntary restraint and assistance. The act of Defecation (as of Urination) chiefly depends upon the combined contraction of the abdominal muscles, similar to that which is concerned in the expiratory movement, but, the glottis being closed so as to prevent the upward motion of the diaphragm, their force acts only on the contents of the abdominal cavity; and so long as the sphincter of the cardia remains closed, it must press downwards upon the walls of the rectum and bladder, —the contents of the one or the other of these cavities, or of both, being expelled, according to the condition of their respective sphincters. These actions are doubtless assisted by the contraction of the walls of the rectum and bladder themselves; for we sometimes find their agency sufficient to expel the contents of the cavities, when there is a total paralysis of the ordinary expulsors, provided that the sphincters be at the same time sufficiently relaxed. This is more especially the case, when their power is augmented by increased nutrition For example, in many cases of disease or injury of the Spinal Cord, the bladder ceases to expel its contents, through the interruption of the circle of reflex action; but after a time, the necessity for drawing-off the urine by the catheter is found to exist no longer, the fluid being constantly expelled as soon as it has accumulated in small quantities. In such cases, the mucous coat is found after death to be thickened and inflamed, and the muscular coat to be greatly increased in strength, and contracted upon itself. It would seem, then, that the abnormal irritability of the mucous membrane, and the increased nutrition of the muscular substance which appears consequent upon it, enable the latter to expel the urine without the assistance of the ordinary expulsors.

plexus of capillary blood-vessels (Fig. 9). Their development commences from a simple canal, sending off bud-like processes, which opens from the mouth, and lies amidst a cellular blastema; and as their evolution advances, the large parent-cells of this blastema form communications with the gland-canal, which is at the same time extending its ramifications, and remain as the terminal follicles of these.

Fig. 9.

Capillary Network around the follicles of the *Parotid Gland.*

91. The inquiry into the chemical constitution and properties of the Saliva had for the most part been limited, until recently, to the fluid obtained from the mouth, rather than to that secreted by the glands; but late researches have shown, that the characters of the fluids poured-forth respectively from the three principal glands are by no means identical; and that the buccal mucus has a very important share in the operations of that mixed product, which constitutes the ordinary Saliva. The specific gravity of this fluid is usually (according to Lehmann) from 1004 to 1006; but he states that it may rise to 1008 or 1009, or may sink to 1002, without any indication of coexisting disease: according to Jacubowitsch, however, its average specific gravity is no higher than 1002·6. When examined microscopically, the Saliva is found to contain a small number of minute corpuscles derived from the Salivary glands, and large epithelial scales thrown-off by the buccal mucous membrane. Its reaction is always alkaline in health; but the degree of alkalinity varies, being greatest during and after meals, and least after prolonged fasting, when the fluid is almost neutral.—The following are two of the most recent analyses of this fluid that have been made; the one by the eminent chemist Frerichs,* whose contributions to the Physiology of Digestion are among the most valuable of the results which have been furnished by recent inquiries in this direction; and the other by Jacubowitsch,† under the direction of MM. Bidder and Schmidt.

Dr. Frerichs.	
Water	994·10
Solid Matters	5·90
Ptyalin, with a little alcohol-extract	1·41
Mucus and epithelium	2·13
Fatty matter	·07
Sulphocyanide of potassium	·10
Alkaline and Earthy Chlorides, Phosphates; Oxide of Iron	2·19
	100·00

Jacubowitsch	
Water	995·16
Solid Matters	4·84
Soluble Organic matter (Ptyalin)	1·34
Epithelium	1·62
Sulphocyanide of potassium	·06
Fixed Salts—Phosphates of soda, lime and magnesia	·98
" Chlorides of Sodium and Potassium	·84
	100·00

* "See "Canstatt's Jahresbericht," 1850, p. 136; and "Wagner's Handworterbuch," band iii., Art. 'Verdauung.'

† Inaugural Dissertation, "De Salivâ," Dorpati, 1848; see also Bidder and Schmidt, "Die Verdauungssaefte und der Stoffwechsel," 1852.

amount of solid matters, in which the organic components, however, be a smaller proportion to the salts, than they do in the fluid of the oth two glands. Now it has been observed by Bernard, that the flow saliva which takes place during mastication proceeds almost entirely fr the parotid and sublingual glands; whilst, during the act of deglutitio when the tongue carries the bolus back into the pharynx, the secreti of the submaxillary is the greatest. Hence it seems reasonable to co clude, that the purpose of these secretions is not identical, that of t parotid and sublingual being to saturate the food, when mixed-up with in the act of mastication, whilst that of the submaxillary seems rath destined to facilitate deglutition.* The fluids which are secreted by t three principal glands, moreover, appear (from the experiments to presently cited) to have very different degrees of efficacy, in produci that chemical change in the food which it is the peculiar attribute of th secretion to exert (§ 93). Of the quantity of Saliva which is secrete daily, it is impossible to form an exact estimate, since it varies great with the character of the food ingested, and the frequency with whic that food is taken, the secreting process being, indeed, almost suspende when the masticator muscles and tongue are completely at rest, unle excited by a nervous stimulus.† The taste, the sight, or even the idea, o savoury food, is sufficient to cause a flow of saliva, especially after a lon fast: but it is by the masticatory movements that this flow is chiefl promoted, so that the amount poured forth will in a great degree depen upon the duration of these movements,—this, again, being governed by th degree in which the food requires mechanical reduction. It is calculate by MM. Bidder and Schmidt, that the average in Man is at about 3 pounds daily; and high as this estimate seems, yet it is based on dat apparently satisfactory.

93. There can be no doubt that one most important action of th Saliva upon the food, consists in preparing it for the chemical operation to which it is to be afterwards subjected, by promoting its mechanica reduction in the act of mastication, and by facilitating the subsequen admixture of other watery fluids, through the intimacy with which it i incorporated with the alimentary matter. But there can be no doubt that the peculiar ferment of the saliva has itself a chemical action upon the farinaceous elements of food; for it has been experimentally proved to have the power of converting starch or dextrin into grape-sugar. This

* This idea of M. Bernard's was confirmed by the following experiments. He made an opening into the œsophagus of a Horse, from which he drew the alimentary bolus as it descended; and on weighing it, he found that by the imbibition of saliva it had increased *eleven fold*. He next tied Wharton's duct, and found that the animal required 41 minutes to masticate what had previously required only 9 minutes, and the mass, when withdrawn from the œsophagus, was covered with mucus and a glutinous fluid, the interior being dry and friable, and the whole increased in weight only *three and a half* times.— An interesting fact in Comparative Anatomy, which fully confirms the results of the above observations, has recently been brought to light by Prof. Owen; for he has ascertained that in the Great Ant-eater (*Myrmecophaga jubata*), whose enormously elongated tongue is kept moist by a large quantity of a peculiarly viscid saliva, for the purpose of entrapping its prey, the Parotid gland is of no unusual size, whilst the Submaxillary gland extends not only along a great part of the elongated jaws, but backwards into the neck.

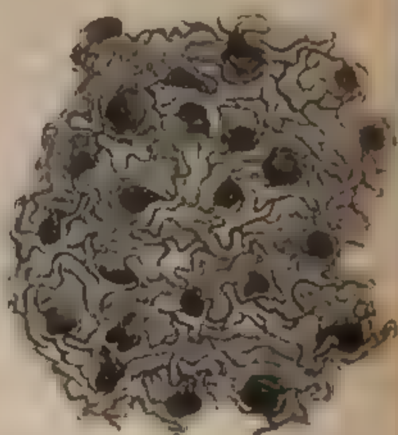
† Of the recent researches by Ludwig, on the influence of the Nervous system on the secretion of saliva, an account will be given in CHAP. XV.

operation of the *Gastric Juice*, which is secreted by the follicles in walls, or by a certain part of them. This follicular apparatus is tremely extensive, and makes-up the chief part of the thickness of gastric mucous membrane. If this be divided by a section perpendicu to the surface (Fig. 10), it is seen to be almost entirely composed o multitude of parallel tubuli closely applied to each other, their ca

Fig. 10.

Vertical section of the *Mucous Membrane of the Stomach*, near the pylorus, A, magnified 3 times, B, magnified 20 times.

Fig. 11.



Capillary network of the lining membrane of the *Stomach*, with the orifices of the *gastric follicles*.

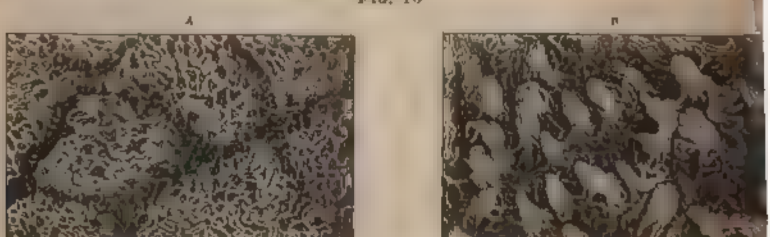
extremities abutting against the submucous tissue, and their open end being directed towards the cavity of the stomach. Between the tubuli blood-vessels pass-up from the submucous tissue, and form a vascular net work on its surface, in the interspaces of which the orifices of the tube are seen (Fig. 11). These tubular glands, however, have not everywhere the same structure. In that which may be considered as their most characteristic form, and which presents itself over the greater part of the area of the membrane, the wide open orifice leads to a pit of no great depth (Fig. 12, *a*), lined by cylinder-epithelium resembling that of the surface with which it is continuous; and from the bottom of this pit, two or more passages (*b*, *b*) branch-off, still lined by cylinder-epithelium, which speedily subdivide into the proper glandular cæca (*c*, *c*). Each of these cæca, when sufficiently magnified (Fig. 13), is found to be composed of a delicate basement-membrane (*a*), inflected over a series of nearly globular cells (*b*), which occupy almost the whole cavity of the tube, and which contain a finely granular matter; the narrow passage left vacant in the centre, however, is still surrounded by a layer of epithelial cells (*c*), whose small size is in striking contrast to the large

simply to furnish mucus for the protection of the membrane. For in Pig, in which the limitation of the two kinds of glands to particular reg of the stomach (the former to the great curva and the middle portion, the latter to the py portion,) is well marked, it has been found by experiments of Zoll and Kolliker, that only follicles with globular cells furnish a fluid pos ing an acid reaction and a solvent power for pro compounds, the secretion of the follicles lined cylinder-epithelium being destitute of both th properties, but agreeing with ordinary mucus. appears, moreover, that whilst the cylinder-epi lium is continually in course of exuviation renewal (the coating of mucus being appare furnished by the disintegration of its cells), glandular epithelium is more permanent; the pe liar contents of its cells being probably drawn by them from the surrounding blood, and be discharged by transudation into the central pass of each cæcum, without any frequent renewal the cells themselves.* According to M. Cl. B nard, when the stomach is empty, the cylindri epithelium which lines them completely blocks their orifices, so that during fasting these appear slightly prominent papillæ; but when the secreti of gastric fluid commences, this epithelium is ca forth by the pressure from beneath.† The inter surface of the stomach, though thrown by contr tion when the viscus is empty into irregular folds ruge (Fig. 16, A), is destitute of those villous pr longations which are so peculiarly characteristic of the mucous surface the intestines; near the pyloric orifice, however, rudimentary villi prese themselves (B).‡

Fig. 15

Mucous gastric gland, with cylinder-epithelium; *a*, wide trunk; *b*, *b*, its cæcal appendages.

Fig. 16



Appearance of the lining membrane of the *Stomach*, in an injected preparation: A, from the convex surface of the rugæ; B, from the neighbourhood of the pylorus, where the orifices of the gastric follicles occupy the interspaces of the deepest portions of the vascular network.

* The best account of the structure of the mucous membrane of the stomach, and the gastric glands, is given by Messrs. Todd and Bowman, "Physiological Anatomy," vol. ii. pp. 190 et seq.; and by Prof. Kolliker, "Mikroskopische Anatomie," band ii. § 16

† "Gazette Medicale," Mars, 1844.

‡ This fact was first brought into prominent notice by Dr. Neill, in his Memoir "O

other Chemists, is the true source of the Hydrochloric acid which may be always obtained from the gastric juice by this method, and it is affirmed by them that Lactic acid is the real agent in the solvent process to which that fluid is subservient, the presence of free lactic acid in the stomach having been determined by other means. But however true this conclusion may be in regard to dogs and pigs, which are the animals that have been chiefly experimented-on for this purpose, it is questionable how far it is fairly applicable to Man. In the first place, the great readiness with which hydrochloric acid was obtained by Prof. Dunglison from the pure gastric fluid drawn from the stomach of Alexis St. Martin, and the fact that the smell of hydrochloric acid might be distinctly recognized in the fresh juice,* are strong evidences in favour of the belief that (as originally maintained by Dr. Prout) free hydrochloric acid is present in this fluid, and that it is the principal if not the only source of its acidity. And an opportunity having been afforded to Dr. Bence Jones, of obtaining a fluid continually vomited in large quantities from the stomach of a patient affected with Sarcina ventriculi, and this fluid, which presented all the ostensible characters of Gastric juice, having been placed in the hands of Prof. Graham for examination, this distinguished Chemist has succeeded in separating hydrochloric acid from it by his method of 'liquid diffusion,' which is not open to the objection that applies to distillation; and although he has found free lactic acid to be also present, its quantity is comparatively small.† The truth appears to be, that both the hydrochloric and lactic acids may give to the gastric fluid the peculiar solvent power, which (as will be presently shown) it possesses for albuminous substances, and that one may take the place of the other; so that whilst in Man, hydrochloric acid is the chief source of the acidity, lactic acid may be so in the dog and pig. Acetic, butyric, and phosphoric acids have also been occasionally met-with in the gastric fluid; but they can scarcely be reckoned among its normal constituents.

97. The peculiar organic 'ferment' of the Gastric juice, to which the name of *Pepsin* has been given, was first obtained in an isolated state by Wasmann; who has given the following account of the properties and reactions of that which he procured from the mucous membrane of the stomach of the Pig, which greatly resembles that of Man. When this membrane is digested in a large quantity of water at from 85° to 95°, many other matters are removed from it besides pepsin; but if this water be poured-off, and the digestion be continued with fresh water in the cold, very little but pepsin is then taken-up. Pepsin appears to be but sparingly soluble in water; when its solution is evaporated to dryness, there remains a brown, greyish, viscid mass, with the odour of glue, and having the appearance of an extract. The solution of this in water is turbid, and still possesses a portion of the characteristic power of pepsin, but greatly reduced. When strong alcohol is added to a fresh solution of pepsin, the

* See Prof. Dunglison's "Human Physiology," 7th edit., vol. i. pp. 585–6.

† For his knowledge of this fact, the Author is indebted to Prof. Graham.—That Hydrochloric acid is the source of the acidity of the gastric juice has also been maintained by Enderlin ("Canstatt's Jahresbericht," 1843, p. 149), and recently by Hubbenet ("Disquisitiones de Succo Gastrico," diss. inaug., Dorpat, 1850), by Bidder and Schmidt ("Die Verdauungssaefte und der Stoffwechsel"), and by Gruenewaldt and Schroeder in their Theses just cited.

escapes through the pyloric orifice, the acidity of the stomach diminishes; and as soon as its cavity is emptied, the secretion of its walls is neutral again.* The quantity of fluid thus poured-forth from the walls of the stomach, may be approximatively estimated from the amount of albuminous matter known to be dissolved by it, but the result must depend upon the solvent power which it is assumed to possess. And thus, whilst Lehmann considers that *four pounds* daily would suffice, it is asserted by Bidder and Schmidt that from *fourteen to seventeen pounds* daily will be required.

99. A very important series of observations on the conditions under which the Gastric juice is secreted, was made some years since by Dr. Beaumont, in the remarkable case of Alexis St. Martin, already several times referred to.† "The inner coat of the stomach (as seen through the fistulous orifice) in its natural and healthy state, is of a light or pale pink colour, varying in its hues, according to its full or empty state. It is of a soft or velvet-like appearance, and is constantly covered with a very thin, transparent, viscid mucus, lining the whole interior of the organ. By applying aliment or other irritants, to the internal coat of the stomach, and observing the effect through a magnifying glass, innumerable lucid points, and very fine [nervous or vascular] papillæ can be seen arising from the villous membrane, and protruding through the mucous coat, from which distils a pure, limpid, colourless, slightly viscid fluid." (The papillæ here described appear to be the orifices of the gastric follicles, which are usually closed by their epithelial cells during fasting, and which would seem to become prominent when the *vis a tergo* of the secreted fluid first causes this plug of cells to be cast forth.) "The fluid thus excited is invariably distinctly acid. The mucus of the stomach is less fluid, more viscid or albuminous, semi-opaque, sometimes a little saltish, and does not possess the slightest character of acidity. The gastric fluid never appears to be accumulated in the cavity of the stomach while fasting; and is seldom, if ever, discharged from its proper secerning vessels, except when excited by the natural stimulus of aliment, mechanical irritation of tubes, or other excitants. When aliment is received, the juice is given out in exact proportion to its requirements for solution, except when more food has been taken than is necessary for the wants of the system."—The observations of Dr. Beaumont have been confirmed by those of M. Blondlot‡ and of M. Cl. Bernard,§ which were made upon Dogs in whose stomachs fistulous openings were maintained for a length of time. They found that the flow of gastric fluid is more excited by pepper, salt, and soluble stimulants, than it is by mechanical irritation; and that if mechanical irritation be carried beyond certain limits, so as to produce pain, the secretion, instead of being more abundant, diminishes or ceases entirely; whilst a ropy mucus is poured-out instead, and the movements of the stomach are considerably increased. The animal at the same time appears ill at ease, is agitated, has nausea, and, if the irritation be continued, actual vomiting; and bile has been observed to flow into

* See Dr. Bence Jones, in "Medical Times," June 14, 1852.

† See Dr. Beaumont's "Experiments and Observations on the Gastric Juice and the Physiology of Digestion," reprinted with notes by Dr. Andrew Combe, Edinb., 1838.

‡ "Traité Analytique de la Digestion."

§ "Archiv. d'Anat. Gén. et de Physiol.," Jan. 1846.

sometimes red and dry, at other times pale and moist, and loses its smooth and healthy appearance; the secretions become vitiated, greatly diminished, or even suppressed; the coat of mucus scarcely perceptible, the follicles flat and flaccid, with secretions insufficient to prevent the papillæ from irritation. There are sometimes found, on the internal coat of the stomach, eruptions of deep-red pimples, not numerous, but distributed here and there upon the villous membrane, rising above the surface of the mucous coat. These are at first sharp-pointed, and red, but frequently become filled with white purulent matter. At other times, irregular, circumscribed red patches, varying in size and extent from half an inch to an inch and a half in circumference, are found on the internal coat. These appear to be the effects of congestion in the minute blood-vessels of the stomach. There are also seen at times small aphthous crusts, in connection with these red patches. Abrasion of the lining membrane, like the rolling-up of the mucous coat into small shreds or strings, leaving the papillæ bare for an indefinite space, is not an uncommon appearance. These diseased appearances, when very slight, do not always affect essentially the gastric apparatus. When considerable, and particularly when there are corresponding symptoms of disease,—as dryness of the mouth, thirst, accelerated pulse, &c.—*no gastric juice can be extracted by the alimentary stimulus.* Drinks are immediately absorbed or otherwise disposed-of; but food taken in this condition of the stomach remains undigested for twenty-four or forty-eight hours, or more, increasing the derangement of the alimentary canal, and aggravating the general symptoms of disease. After excessive eating or drinking, chymification is retarded; and, though the appetite be not always impaired at first, the fluids become acrid and sharp, excoriating the edges of the aperture, and almost invariably producing aphthous patches and the other indications of a diseased state of the internal membrane. Vitiated bile is also found in the stomach under these circumstances, and flocculi of mucus are more abundant than in health. Whenever this morbid condition of the stomach occurs, with the usual accompanying symptoms of disease, there is generally a corresponding appearance of the tongue. When a healthy state of the stomach is restored, the tongue invariably becomes clean."*

101. That the secretion of Gastric Juice is affected in a very marked manner by conditions of the Nervous system, is indicated by the effect of

* Dr A. Combe's commentary on the above passage is too apposite to be omitted. "Many persons who obviously live too freely, protest against the fact, because they feel no immediate inconvenience, either from the quantity of food, or the stimulants in which they habitually indulge; or, in other words, because they experience no pain, sickness, or headache,—nothing, perhaps, except slight fulness and oppression, which soon go off. Observation extended over a sufficient length of time, however, shows that the conclusion drawn is entirely fallacious, and that the real amount of injury is not felt at the moment, merely because, for a wise purpose, nature has deprived us of any consciousness of either the existence or the state of the stomach during health. In accordance with this, Dr. Beaumont's experiments prove, that extensive erythematic inflammation of the mucous coat of the stomach was of frequent occurrence in St. Martin after excesses in eating, and especially in drinking, even when no marked general symptom was present to indicate its existence. Occasionally, febrile heat, nausea, headache, and thirst were complained of, but not always. Had St. Martin's stomach, and its inflamed patches, not been visible to the eye, he too might have pleaded that his temporary excesses did him no harm; but, when they presented themselves in such legible characters that Dr Beaumont could not miss seeing them, argument and supposition were at an end, and the broad fact could not be denied."

intestinal canal, and the existence of chyle in the lacteals. It may serve to account in some degree for the contrary results obtained by other experimenters, to state that seven out of Dr. R.'s seventeen experiments were performed, before he obtained any evidence of digestion after the operation, and that the four which furnished this followed one another almost in succession; so that it is easy to understand why those, who were satisfied with a small number of experiments, should have been led to deny it altogether.—Another series of experiments was performed by Dr. Reid, for the purpose of testing the validity of the results obtained by Sir B. Brodie, relative to the effects of section of the Par Vagum upon the secretions of the stomach, after the introduction of arsenious acid into the system. According to that eminent Surgeon and Physiologist,* when the poison was introduced after the Pneumogastric had been divided on each side, the quantity of the protective mucous and watery secretions was much less than usual, although obvious marks of inflammation were present. In order to avoid error as much as possible, Dr. Reid made five sets of experiments, employing two dogs in each, as nearly as possible of equal size and strength, introducing the same quantity of the poison into the system of each in the same manner, but cutting the Vagi in one, and leaving them entire in the other. This *comparative* mode of experimenting is obviously the only one admissible in such an investigation. Its result was in every instance opposed to the statements of Sir B. Brodie; the quantity of the mucous and watery secretions of the stomach being nearly the same in each individual of the respective pairs subjected to experiment; so that their production can no longer be referred to the influence of the Pneumogastric nerves. Moreover, the appearances of inflammation were, in four out of the five cases, greatest in the animals whose Vagi were left entire; and this seemed to be referable to the longer duration of their lives after the arsenic had been introduced. The results of Sir B. Brodie's experiments are perhaps to be explained by the speedy occurrence of death in the subjects of them, consequent (it may be) upon the want of sufficiently free respiration, which was carefully guarded-against by Dr. Reid.

103. It must be held as demonstrated by these experiments, then, that all the arguments which have been drawn from the effects of lesion of the Pneumogastrics upon the functions of the Stomach, in favour of the doctrine that Secretion *depends upon* Nervous agency must be set aside. That these nerves have an important *influence on* the gastric secretion, is evident from the deficiency in its amount soon after their section, as well as from other facts. But this is a very different proposition from that just alluded-to; and the difference has been very happily illustrated by Dr. Reid. "The movements of a horse," he observes, "are independent of the rider on his back,—in other words, the rider does not furnish the conditions necessary for the movements of the horse;—but every one knows how much these movements may be influenced by the hand and heel of the rider." It may be hoped, then, that physiologists will cease to adduce the oft-cited experiments of Dr. Wilson Philip, in favour of the hypothesis (for such it must be termed) that secretion is dependent upon nervous influence, and that this is identical with galvanism. Additional

* "Philosophical Transactions," 1814, p. 102

whey. After standing at rest a few minutes, a fine sediment of the colour of the meat subsided to the bottom of the vial.—A piece of beef, exactly similar to that placed in the vial, was introduced into the stomach, through the aperture, at the same time. At 12 o'clock it was withdrawn, and found to be as little affected by digestion as that in the vial; there was little or no difference in their appearance. It was returned to the stomach; and, on the string being drawn out at 1 o'clock, P.M., the meat was found to be all completely digested and gone. The effect of the gastric juice on the piece of meat suspended in the stomach, was exactly similar to that in the vial, only more rapid after the first half-hour, and sooner completed. Digestion commenced on, and was confined to, the surface entirely in both situations. Agitation accelerated the solution in the vial, by removing the coat that was digested on the surface, enveloping the remainder of the meat in the gastric fluid, and giving this fluid access to the undigested portions."* Many variations were made in other experiments; some of which strikingly displayed the effects of thorough mastication, in aiding both natural and artificial digestion.

105. The attempt was made by Dr. Beaumont, to determine the relative digestibility of different articles of diet, by observing the length of time requisite for their solution.† But, as he himself points-out, the rapidity of digestion varies so greatly, according to the quantity eaten, the nature and amount of the previous exercise, the interval since the preceding meal, the state of health, the condition of the mind, and the nature of the weather, that a much more extended inquiry would be necessary to arrive at results to be depended-on. Some important inferences of a general character, however, may be drawn from his researches.—It seems to be a general rule, that the flesh of wild animals is more easy of digestion, than that of the domesticated races which approach them most nearly. This may, perhaps, be partly attributed to the small quantity of fatty matter that is mixed-up with the flesh of the former, whilst that of the latter is largely pervaded by it. For it appears from Dr. B.'s experiments, that the presence in the stomach of any substance which is difficult of digestion, interferes with the solution of food that would otherwise be soon reduced. It seems that, on the whole, Beef is more speedily reduced than Mutton, and Mutton sooner than either Veal or Pork. Fowls are far from possessing the digestibility that is ordinarily imputed to them; but Turkey is, of all kinds of flesh except Venison, the most soluble.—Dr Beaumont's experiments further show, that *bulk* is as necessary for healthy digestion, as the presence of the nutrient principle itself. This fact has been long known by experience to uncivilised nations. The Kamschatdales, for example, are in the habit of mixing earth or saw-dust with the train oil, on which alone they are frequently reduced to live. The Veddahs or wild hunters of Ceylon, on the same principle, mingle the pounded fibres of soft and decayed wood with the honey on which they feed when meat is not to be had; and on one of them being asked

* Experiments 2 and 3 of First Series.

† It is important to bear in mind, that the digestibility of different substances bears no relation to their nutrient value, which is entirely dependent on their chemical composition. Of course, however nutritious a substance may be, it is valueless as an article of diet if it cannot be dissolved; but, on the other hand, substances which are very easily digested (such as farinaceous matters) may have a low nutritive value, through containing but a very small proportion of azotized constituents.

sion, and are diffused in a state of suspension through the pulpy chyme. The effect of the gastric fluid upon the several kinds of Albuminous matters, is to reduce them to a state of complete solution, and at the same time to alter their chemical properties, so that they for the most part lose their distinctive attributes, and are brought to one uniform condition, that of *albuminose* (a kind of imperfect albumen), which seems to be the state best adapted for subsequent assimilation. In this condition, they seem to form definite combinations with the solvent fluid, which have received the name of *peptones*. That these combinations, however, are very different from mere solutions of the same matters in acidulated liquids, has been shown by the experiments of M. Bernard, who found that, on injecting the solution of albumen in very dilute hydrochloric acid into the general circulation, the liquid speedily passed off by the renal secretion; whilst after injecting the solution of albumen in gastric juice, no trace of this could be detected in the urine. Hence it seems evident that a *converting* power is exerted by the pepsin, or peculiar 'ferment' of the gastric fluid, whilst the *solvent* power is due to the acid; a conclusion which agrees well with that based on other evidence (§ 97). It appears from the observations of MM. Blondlot and Bernard, that when liquid Albumen is taken into the stomach, it does not undergo complete coagulation before the solvent process commences, but merely becomes opalescent; Casein, on the other hand, is completely coagulated, the peculiar animal principle of the gastric fluid having more power of precipitating it, than is possessed by any other re-agent. The gastric fluid has also a special solvent power for Gelatinous substances; acting upon those which would have otherwise required long boiling for their disintegration. Here, too, the marked difference in action between the gastric juice and a merely acidulous fluid has been demonstrated by M. Bernard; who has shown that, when a piece of bone is submitted to the latter, its mineral portion alone is affected by it; whereas when it is subjected to the former, the gastric juice digests the gelatin, and leaves the phosphates and carbonates unaltered. Moreover, a decided transformation is effected by the operation of the gastric fluid: for the gelatin of the peptone has lost its power of gelatinizing, and is not precipitated by chlorine.

107. This action of the Gastric solvent upon the azotized constituents of the food, is dependent upon several accessory conditions. One of the most important of these is *temperature*. A heat of from 96° to 100° is required to keep-up the solvent process, which is retarded according to the depression of the thermometer below this standard; so that at the ordinary temperature of the atmosphere it is completely suspended, to be renewed, however, with an increment of heat. On the other hand, a trifling elevation of temperature above 100° occasions a decomposition in the gastric juice, which entirely destroys its solvent power.—The next condition, which specially affects the time required for the process of solution, is *motion*. This does not act mechanically, by way of 'trituration,' as was once supposed, for food is found to be digested, when enclosed in metallic balls perforated to admit the access of gastric juice to their interior. But it answers the purpose of thoroughly subjecting the whole of the alimentary bolus to the agency of the gastric solvent, by bringing each part successively into contact with the lining membrane

It is remarkable, however, that in the Dog, the solid residue (accord to Schmidt) should be nearly 10 per cent. or even more, and that should be almost entirely composed of organic matter, the inorganic c stituents being in no larger amount than in the pancreatic fluid of ass. The difference in the nature of the alimentary materials on wh the pancreatic fluids of these two animals are destined to act, is probab the explanation of this marked variation in their composition.—T albuminous 'ferment' is not perfectly coagulable by heat, and when p cipitated by alcohol it redissolves readily in water; it is precipitated sulphuric, nitric, and concentrated hydrochloric acid, and by the meta salts; and when thrown down by these, or by heat, it is redissolved alkalies. It is also precipitated by acetic acid; but it slowly redissolv in an excess of the reagent, and on the application of heat; and fro this solution it is precipitated by ferrocyanide of potassium. Wh boiled with ammonia, it assumes an intense yellow colour. The readine with which this substance undergoes change, is indicated by the rapidi with which the pancreatic fluid passes into decomposition; for even af a few hours' exposure to the air, it gives-off a decidedly putrid odou Like ptyalin, though in a less degree, this peculiar constituent of th pancreatic fluid possesses the power of converting starch into sugar, the can be no doubt, therefore, that it is subservient to the continued dige tion of the farinaceous part of the food, during its passage through th small intestines. It shares this office, however, with the 'succus ent ricus,' which has been shown by Frerichs and Hubbenet to be al possessed of this converting power.

109. It has recently been affirmed by M. Cl. Bernard, and stron evidence has been adduced by him in support of his statement, that th *essential* purpose of the Pancreatic fluid is to promote the absorption o fatty matters, by reducing them to the state of an *emulsion*, which i capable of finding its way into the lacteals.* That this fluid possesse the emulsifying power in a peculiar degree, may be considered as having been fully demonstrated by his experiments; for on mixing it with oil butter, or any variety of fat, at a temperature sufficiently high to render the fatty substance liquid, and then stirring the mixture for a few minutes, an emulsion is produced bearing a strong resemblance to chyle. This emulsion does not cease to present its peculiar aspect although left standing for some time; whereas although bile, saliva, gastric juice, blood serum, and other animal fluids, have a certain emulsifying power, yet after a short time the oil particles run together again, almost as if they had been merely shaken up with water. Further, it is asserted by Bernard, that in the Rabbit (in which the pancreatic

* "Archiv Génér de Méd.," tom xix. It has been assumed by Frerichs, Lenz, and other objectors to M. Bernard's views, that he maintains that the pancreatic fluid *saponifies* the neutral fatty matters taken-in as food, converting them into fatty acids and glycerine whilst yet within the intestinal canal. It is no doubt true that M. Bernard considers that some such transformation takes place in the body, before the fatty matter is ultimately disposed of; but he constantly speaks of the *emulsifying* power as the peculiar attribute of the pancreatic fluid, and only asserts that saponification takes place in artificial digestion, when the fluid is left for some time in contact with fatty substances; so that the Author is inclined to regard the objections above alluded-to, as having arisen from a misapprehension of M. Bernard's meaning. (See also Dr. Donaldson's account of M. Bernard's discoveries, in the "Amer. Journ. of Med. Sci.," Oct. 1851.)

are vitiated by the fact, that the pancreatic duct in most cases discha[rges] itself into the intestinal tube at the same point with the hepatic, [and] has thus been frequently involved in operations performed upon it.—[As] the most important constituents of Bile, and the agency of the Liv[er as] an assimilating and depurating organ, will be more appropriately c[on]sidered elsewhere (CHAPS. IV. and IX.), we shall here limit ourselves to [the] consideration of what may be regarded as the best-established fact[s in] regard to the uses of the biliary secretion in the digestive proc[ess.]

111. When its action is tested out of the body, by mingling it w[ith] the different constituents of food, it is found to exert no change up[on] starchy substances whilst fresh; though, when in a state of incipient [de]composition, it acts upon them as other animal substances do. It has [no] action upon cane-sugar, until it has stood a considerable length of ti[me;] but then it converts it into lactic acid. This change it speedily exe[rts,] as do nearly all other animal substances, upon grape-sugar. It has [no] action on albuminous substances, even when acidulated. And althou[gh] it will form an emulsion with oleaginous matter, yet the emulsificatio[n is] less complete than that which is effected by the pancreatic fluid alon[e.] Hence it appears to be deficient in anything at all similar to the pecul[iar] ferments of the saliva, gastric juice, and pancreatic secretion; and its off[ice] in digestion must be of a different character from that of either of the[se] fluids. The nature of this office may be partly judged-of, from what tak[es] place when fresh bile is mingled with the product of gastric digestio[n.] The acid reaction of the latter is neutralized by the alkali of the form[er;] and a sort of precipitation takes place (as was originally noticed by D[r.] Beaumont), in which certain constituents of the bile fall down, and i[n] which also (according to M. Bernard) the albuminous matters that hav[e] been dissolved, though not yet absorbed, are for a time rendered insolubl[e;] leaving the saccharine matters in solution, and the oleaginous floating o[n] the top. The admixture of the bile with the chyme seems further t[o] have the effect of checking destructive chemical changes in its compositio[n.] For M. Bernard found that when two similar pieces of meat had bee[n] immersed for three months, one in a bottle of gastric juice alone, and th[e] other in a mixture of gastric juice and bile, a strong ammoniacal odou[r] resulting from decomposition was emitted from the former, whilst th[e] latter was pure and free from any smell whatever. And it was remarked by MM. Tiedemann and Gmelin (and also recently by Hoffmann), that when the bile was prevented from passing into the alimentary canal, the contents of the latter were more fœtid than usual. Moreover, it is found that the admixture of bile with fermenting substances checks the process of fermentation; and M. Bernard has shown by ingeniously-contrived experiments,† that this antagonistic power is exerted also in the living body. Hence we can understand how the reflux of bile into the stomach should seriously interfere with the process of gastric digestion; and how, when there is a deficient secretion of bile, or more food is swallowed than the bile provided for it can act-upon, or the character of the biliary secretion itself has undergone any serious perversion, there should be much more than the normal amount of putrefactive fermentation, as is indicated by an evolution of flatus, and very frequently by diarrhœa.

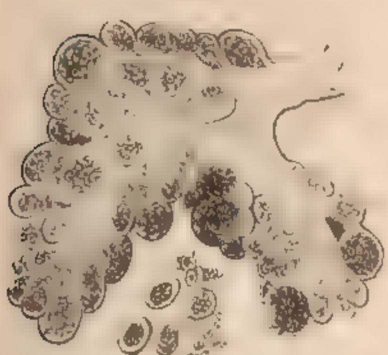
* Dr. Bence Jones, in the "Medical Times," July 5, 1851.

† "Amer. Journ. of Med. Sci.," Oct. 1851, p. 351.

one-eighth of what it is when at its maximum. Still it is obvious, that although its rate is thus greatly influenced by the stage of the digestive process (which is the less to be wondered-at, when it is remembered that the secretion is formed from blood that is charged with newly-absorbed and imperfectly-assimilated matters), the excrementitious character of the secretion requires that its elimination shall be constantly going on to a certain degree; but a receptacle is provided in Man, as in most others among the higher animals whose digestion is performed at intervals, for the storing-up of the fluid until it can be usefully employed in that process. The intestinal orifice of the ductus choledochus is closed by a sort of sphincter; and the fluid secreted during the intervals of digestion, not being propelled with a force sufficient to dilate this, flows back into the gall-bladder, which dilates to receive it. The presence of food in the duodenum seems to excite the walls of the gall-bladder and of the biliary ducts (which contain a large quantity of non-striated muscular fibre), to a contraction sufficiently powerful to propel their contents into the intestine, in spite of the opposition of the sphincter; but whether this takes place through a reflex action of the nervous system, or through the direct stimulation of the muscular coat of the duct by the passage of alimentary matters over its orifice, we have at present no means of satisfactorily determining. It will be recollected that the gall-bladder is usually found distended with bile, in cases of death from starvation (§ 71), notwithstanding the diminution in the amount actually secreted.—Of the bile which is poured into the intestinal tube, by far the greater proportion seems to be re-absorbed (§ 117).

113. Besides the biliary and pancreatic secretions, there is poured into the upper part of the Intestinal canal a fluid secreted in its own walls, which has received the designation of *Succus Entericus*. It seems not improbable that the secretion of this fluid may be the function of the Glands of Brunner, which are small racemose clusters of follicles (Fig. 17), imbedded in the walls of the duodenum, extending also to the commencement of the jejunum. The Intestinal juice appears, from the researches of Bidder and Schmidt,* to be a colourless viscid liquid, invariably alkaline in its reaction, and containing from 3 to 3½ per cent of solid matter.

Fig. 17.



Portion of one of *Brunner's Glands*, from the Human Duodenum.

The total amount daily secreted in Man is estimated by these experimenters at about 7 oz.; the rate of its secretion seems to be most rapid five or six hours after a meal; and its quantity is considerably increased shortly after the ingestion of fluid, and this without any diminution in the

* Op. cit., §§ 260—282; and Lehmann's "Physiologischen Chemie," 2nd edit., band ii., pp. 95—99

completely dissolved. This supposition appeared to derive weight from the fact, that the cæcum is peculiarly large in most Herbivorous animals, the 'appendix vermiformis' being also of greatly increased dimensions and sometimes double. But from the experiments and observations of Blondlot, it seems probable that the acid of the cæcum is rather a product of the transformation of saccharine substances in the alimentary canal than a secretion from its walls.* Still, as this lactic acid has a solvent power for albuminous matters, which is equal, or nearly so, to that exerted by hydrochloric acid, it is by no means impossible that it may be subservient to the completion of the digestive process in the cases in question; since, the larger the proportion of the aliment composed of saccharine matters, the greater will be the importance of a thorough extraction of its albuminous constituents.

115. The Intestinal tube is furnished, throughout its entire length with innumerable simple open glandulæ, the 'follicles of Lieberkuhn;' these are straight narrow cæca, standing side by side, with very little intervening substance (except where the Peyerian bodies lie amongst them), and corresponding in length with the thickness of the mucous membrane. Their orifices are seen in the interspaces between the villi, where they are so closely set-together as to seem like the apertures of a sieve; and they are arranged in rings around the Peyerian glandulæ (Fig. 20). The precise nature of their secretion is unknown, and it seems not improbable that notwithstanding the close resemblance which they bear to one another in anatomical characters, there may be some variety of function among them. Thus it is likely that some of them (like the mucous glandulæ of the stomach) are everywhere destined to supply a protective mucus; whilst some of those in the higher part of the intestinal tube may furnish the succus entericus; and some of those in the lower may be concerned in the elimination of that peculiarly fæcal matter, which seems to be rather an excretion from the blood, than the result of the decomposition of any constituents of the food (§ 118).

116. The undigested residue of the food, mingled with the products of secretion that have been poured into the alimentary canal, gradually acquires, in the large intestine, the ordinary consistency of Fæces, through the continuance of the absorbent process, whereby the superfluous fluid is removed. The condition of this residue has been particularly studied by Dr. Rawitz, who examined microscopically the products of the artificial digestion of different kinds of aliment, and the contents of the fæces of different animals that had eaten the same articles. "The general results of his examinations, as regards *animal* food, show that the muscular tissue breaks-up into its constituent fasciculi, and that these again are divided transversely; gradually the transverse striæ become indistinct and then disappear; and finally the sarcolemma seems to be dissolved, and no trace of the tissue can be found in the chyme, except a few fragments of fibres. These changes ensue most rapidly in the flesh of fish and hares, less rapidly in that of poultry and other animals. The fragments of muscular tissue which remain after the continued action of the digestive fluid, do not appear to undergo any alteration in their passage through the rest of the intestinal canal, for similar fragments may be

* See his "Traité analytique de la Digestion," p. 103.

composition of the Organic portion of the Fæces is attended with so much difficulty and unpleasantness, that it has hitherto been scarcely prosecuted systematically. According to the recent enquiries of Dr. Marcet,* healthy human excrements contain,—1. A peculiar crystalline substance, having an alkaline reaction, containing both nitrogen and sulphur, fusing at about 203°, and at a higher temperature burning away without inorganic residue; this he proposes to call *Excretine*. 2. A fatty acid, having the properties of Margaric acid, but not constantly present; 3. A colouring matter, similar to that of blood and urine; 4. A light granular colourless substance, sparingly soluble in ether, fusible by heat, and burning with a bright fuliginous flame, leaving a white residue composed of phosphate of potash; this is probably a combination of phosphate of potash with a pure organic substance. 5. An acid olive-coloured substance of a fatty nature, termed *Excretolic* acid; this is probably united in fæces with excretine or a basic substance closely allied to it. Neither butyric nor lactic acid could be discovered in healthy Human excrement; although the former presents itself in the excrements of Carnivorous Mammalia, which contain also a substance allied in its nature to excretine, but not identical with it.

117. Of the degree in which the Bile, as a whole, normally enters into the composition of the fæces, it is difficult to speak with precision. Its principal constituents can easily be recognized in the upper part of the small intestine; but the further we descend in the intestinal canal, the less of them do we meet with; and in the contents of the large intestine, and in the evacuated fæces, they are seldom to be discovered. How far this result depends upon their removal from the alimentary canal by re-absorption, and how far upon the loss of their characteristic properties by decomposition, cannot be stated with certainty. That the colouring-matter of the fæces is in great part derived from the bile, is shown by their paleness when that secretion is not duly poured into the intestinal tube. And it is probable that the peculiar fatty substances just described, are products of the metamorphosis of its oleaginous and resinous matters. The similarity which has been found to exist between the odour of certain components of putrefying bile, and that of fæces, has led Prof. Valentin to suppose that the matter which gives to the latter their characteristic smell, is entirely derived from decomposing bile. We shall presently see, however, that other sources of this matter probably exist (§ 118); and the recent researches of Bidder and Schmidt upon the amount of *sulphur* in the fæces, appear to show that not above one-eighth of the solid matter of the bile is normally excreted under this form. The indications of the presence of bile are more distinct, however, when the fæces have remained for only a short time in the large intestine, and when there has consequently been less time for its re-absorption. In the fæcal discharges which result from the action of mercurials, large quantities of biliary matter may be detected, very little changed.

118. Although it cannot be stated with certainty, what is the precise portion of the Glandular apparatus connected with the Intestinal canal, which is concerned in the elimination of that peculiarly putrescent matter which gives to the fæces their characteristic odour, yet it may be

* "Proceedings of the Royal Society," June 15, 1854.

medicine, gives us a most valuable means of augmenting its depurative action. Seeing, as no observant Medical Practitioner can avoid doing, how frequently Nature herself employs this means of eliminating morbific matter from the system,—as is shown by the immense relief often given by an attack of diarrhœa,—we may look upon this apparatus as one which, like the Liver, the Kidney, or the Skin, may frequently with propriety be stimulated by medicines that have a special action upon it, and one through which some morbific matters may be got rid of more certainly and more speedily than through any other channel.—It is not intended by these observations to encourage the system of violent and indiscriminate purgation; but to show that purgatives, judiciously administered, often constitute our best means of eliminating injurious matters from the system.

CHAPTER IV

OF ABSORPTION AND SANGUIFICATION.

1. *Of Absorption from the Digestive Cavity.*

119. So long as the Alimentary matter remains in the Digestive cavity, however perfect may be its state of preparation, it is as far from being conducive to the nutrition of the system, as if it were in contact with the external surface. It is only when absorbed into the vessels, and carried by the circulating current through the very substance of the body, that it becomes capable of being appropriated by its various tissues and organs. In Man, as in nearly all vertebrated animals, a set of vessels is interposed between the walls of the intestine and the sanguiferous system; for the purpose, as it would seem, of taking-up certain components of the nutritive matter, of which part at least are not in a state of perfect solution, and of preparing them for being introduced into the current of the blood. These are the *Absorbents* of the intestinal walls; of which those that are found, after the performance of the digestive process, to contain the white opalescent fluid known as 'chyle,' are distinguished as *lacteals;* while the remainder, like the absorbents of the system generally, are known as *lymphatics.* The distinction is a purely artificial one; for the 'lacteals' are the 'lymphatics' of those parts of the intestinal walls which they supply, as is shown by the fact that, during the intervals of the digestive process, they contain a transparent fluid in all respects similar to the 'lymph' of other parts.—The Absorbents form a minute plexus beneath the mucous lining of the alimentary canal along its whole extent; but in the small intestine they enter the villi, at the extremities of which, indeed, they may be said to commence. Those only are entitled to the designation of 'lacteals,' which originate from the intestinal canal below the point at which the biliary and pancreatic ducts pour their contents into it; for above that point, the fatty constituents of the alimentary matter are not in a state of sufficiently fine division to enter them; and the absorbed fluid is consequently pellucid, instead of possessing the milky aspect. Thus, then, we are to consider the *lacteal* portion of the Absorbent system, to

numerous muscular fibre-cells, and that they present themselves in very different degrees of contraction and extension. This observation confirms the statement formerly made by M. Lacauchie* as to the existence of contractile tissue in the villi, which statement was based on the contraction which he had observed them to undergo after their removal from the body; and also the yet more remarkable assertion of MM. Gruby and Delafond, that rhythmical movements of contraction and extension in different directions take place in the villi whilst absorption is going-on,† which have an important influence on the propulsion of the fluids contained within their vessels.

121. When the Villi are examined at such a period after a meal containing oleaginous matters, as has sufficed for its partial digestion, their lacteals are seen to be turgid with chyle (Fig. 19, A); and the extremity

Fig. 19.

Extremity of *Intestinal Villus*, seen at A, during absorption, and showing absorbent cells and lacteal trunks, distended with chyle; at B, during interval of digestion, showing the supposed peripheral network of lacteals.

of each lacteal appears to be imbedded in a collection of globules presenting an opalescent appearance, which gives to the end of the villus a somewhat mulberry-like form. It was supposed by Prof. Goodsir,‡ by whom this appearance was first observed, that these globules are cells developed *within* the basement-membrane,§ during the act of absorption, from what he considered to be granular germs visible in the same situation during the intervals of the process (B); and that these cells, drawing into themselves during their growth certain of the nutritive materials contained in the intestinal canal, are thus the real agents in the *selection* of the substances which are to be introduced into the lacteals, delivering them to these, by the rupture or deliquescence of their walls, so soon as their own term of life is ended. It was further held by Prof. Goodsir, that the epithelium-cells covering the extremities of the villi fall-off during the process of absorption, so as to leave the villi more free to imbibe the fluids in contact with their surface; and thus that a new set of absorbent cells is developed with every recurrence of the act of absorption, and a new set of protective epithelium-cells in the subsequent interval. These views, however, though correctly indicating the fact that the elements of chyle are introduced into the lacteals by

* "Etudes Hydrotomiques et Micrographiques," Paris, 1844, p. 50.

† "Comptes Rendus," 1842, p. 1199, and 1843, p. 1195.

‡ "Edinb. New Phil. Journ.," July, 1842, and "Anatomical and Pathological Observations," pp. 5–10.

§ The epithelium-cells of the villi may frequently be observed to be connected at their free extremities by something like a continuous membrane; and it was doubtless this, which was mistaken by Prof. Goodsir for the proper basement-membrane that underlies the epithelium cells.

in three other instances within $2\frac{1}{2}$ minutes. In all these cases, however, the stomach may be presumed to have been empty, and the vascular system in a state of aptitude for absorption; since the experiments were made either after a long fast, or at least four hours after a light meal. When, on the other hand, the salt was introduced into the stomach soon after the ingestion of alimentary substances, a much longer period elapsed before it could be detected in the urine; thus, when a substantial meal had been taken two hours previously, the interval was 12 minutes; when tea and bread-and-butter had been taken one hour previously, the interval was 14 minutes; a similar meal having been taken twenty-four minutes previously, the interval was 16 minutes; when only two minutes had passed since the conclusion of such a meal, the interval was 27 minutes; and when a solid meal had been concluded just before the introduction of the salt, the interval was 39 minutes.*—These facts are of great importance, in showing the very marked influence which the state of the *stomach* exercises upon the absorption of matters introduced into it. Not less important, however, is the state of the *vascular system* in regard to turgescence or emptiness; for it was found by Magendie, that when he had injected a considerable quantity of water into the veins of a dog, poison was absorbed very slowly; whilst if he relieved the distension by bleeding, there was speedy evidence of its entrance into the circulation.—The rapidity with which not only aqueous but alcoholic liquids introduced into the stomach may pass into the general circulation, has been shown by the experiments of Dr. Percy;† who found that when strong alcohol was injected into the stomach of dogs, the animals would sometimes fall insensible to the ground *immediately* upon the completion of the injection, their respiratory and cardiac movements ceasing within two minutes; and that on post-mortem examination in such cases, the stomach was nearly empty, whilst the blood was highly charged with alcohol; thus rendering it almost certain, that not merely the final destruction of nervous power, but the imme-

* The great rapidity with which soluble salts, introduced into the stomach, make their appearance in the urine, has led M. Cl. Bernard to think that some more direct channel must exist for their passage from the stomach to the kidneys, than that which the ordinary current of the sanguiferous circulation affords; and to advance the extraordinary doctrine, that whilst absorption is going on, there is a constriction of the vena cava above the entrance of the hepatic vein, whereby a *reflux* of the blood discharged by it takes place, so that it passes into the *renal* vein, without reaching the heart. He asserts that a peculiar thickening of the muscular coat exists in the upper part of the vena cava, whereby its contraction is occasioned; also that there are (in the horse at least) direct passages by which a part of the portal blood may be discharged into the vena cava, without passing through the liver. ("L'Union Medicale," 1849, No. 115.)—Now, in the first place, this hypothesis is not necessary to explain the facts; for, as is shown above, there is evidence of the transmission of substances to *other* parts, with at least as much rapidity as is indicated by their appearance in the urine. And, in the second place, if the supposed reflux really took place, it must affect the whole venous circulation of the trunk and lower extremities, except such as the vena azygos and a few other small channels could provide for; and must occasion (to make good the conditions of the problem) not merely a *stagnation*, but an absolute *reflux*, so that the veins would be metamorphosed into arteries, and the arteries into veins. How the *vis à tergo*, originally derived from the heart, can thus be strong enough at the very end of the systemic circulation, not merely to neutralize, but actually to overcome, the force which it exercises almost close to the heart, M. Bernard has not informed us.

† "Experimental Enquiry concerning the Presence of Alcohol in the Ventricles of the Brain," p. 61.

substances; such as gamboge, madder, and rhubarb, the odorou[s sub]stances were camphor, musk, asafœtida, &c.; while, in other cases, [the] saline bodies, such as chloride of barium, acetate of lead and of m[er]... and some of the prussiates, which might easily be detected by ch[emical] tests, were mixed with the food. The colouring matters, for th[e most] part, were carried out of the system, without being received eith[er by] the veins or the lacteals; the odorous substances were generally d[etected] in the venous blood and in the urine, but not in the chyle; whilst [of the] saline substances, many were found in the blood and in the urine, [but] very few only in the chyle. A similar conclusion might be drawn [from] the numerous instances, in which various substances introduced in[to the] intestines have been detected in the blood, although the thoracic [duct] had been tied; but these results are less satisfactory, because, th[ough] there is probably no direct communication (as maintained by [some]) between the lacteals and the veins in the mesenteric glands, the [par]titions which separate their respective contents are evidently so [thin] that transudation may readily take place through them.

124. This Absorption by the Blood-vessels is a simply *physical* [ac]tion, depending upon the relative consistency and miscibility o[f the] blood and of the liquids to be absorbed, and upon the rapid move[ment] of the blood through the vessels. Where the contents of the alime[ntary] canal are of less specific gravity than the blood, and are capa[ble of] readily mingling with it, an endosmotic current will be establi[shed] through the delicate parietes of the blood-vessels and their thin i[nvest]ments, between the two liquids, the former passing towards the ... and in this mode, albuminous, gelatinous, saccharine, saline, and ... soluble substances may be caused to enter the blood, if their solutio[n be] not too concentrated. But if their density be equal to that of the b[lood,] or nearly so, little or no absorption is likely to take place; and [the] purpose which is answered by the very copious discharge of aqueous [fluid] into the alimentary canal, during the operation of digestion, is obvi[ously] the reduction of the density of the solution to a favourable point. [If,] again, the density of the contents of the alimentary canal should ex[ceed] that of the blood, an endosmotic current might perhaps be establishe[d in] the opposite direction; but their dilution would probably be effecte[d so] speedily, that little of the contents of the blood-vessels would be ... drawn-forth, more especially as animal membranes appear to hav[e a] special power of resisting the passage of Albumen, whilst they give [free] transmission to Albuminose.*—That the movement of blood in ... vessels will vastly increase the rate of endosmotic absorption, is ...

* It is considered by Liebig that the purgative effects of concentrated saline solu[tions] are to be accounted for on this principle,—the establishment of an endosmotic cu[rrent] *from* instead of *towards* the circulating system. It is difficult, however, thus to ac[count] for all the phenomena of saline purgation; and the Author greatly doubts the validi[ty of] the explanation. It may, however, be applied with more probability, to the fact of w[hich] the Author was assured by the late Dr. Prout, viz., that having fed a dog upon ... starch, he had found albumen in the duodenum. On this fact Dr. Prout much relied ... proof of the *convertibility* of starch into albumen,—an idea which would now be uni[ver]sally condemned by Organic Chemists; but it does not seem difficult to believe, that ... presence of a viscid mass of half-digested starch might have determined a transudatio[n of] albumen from the blood-vessels by endosmosis.

Digestive cavity. In the adult condition of most of the higher anim however, the special function of the latter is so much exalted as usu to supersede the necessity of any other supply; and the function of cutaneous and pulmonary surfaces may be considered as rather that exhalation, than of absorption.* But there are peculiar conditions of system, in which the imbibition of fluid through these surfaces is p formed with great activity, supplying what would otherwise be a m important deficiency It may take place either through the direct ap cation of fluid to the surface, or even through the medium of the atm sphere, in which a greater or less proportion of watery vapour is usua dissolved. This absorption occurs most vigorously, when the system h been drained of its fluid, either by an excess of the excretions, or by diminution of the regular supply.

128. It may be desirable to adduce some individual cases, which will this function in a striking point of view, and those may be first notic in which the Absorption took place through the contact of *liquids* w the skin. It is well known that shipwrecked sailors, and others who a suffering from thirst, owing to the want of fresh water, find it grea alleviated, or altogether relieved, by dipping their clothes into the s and putting them on whilst still wet, or by frequently immersing the own bodies.†—In a case related by Dr. Currie, of a patient labouri under dysphagia in its most advanced stage (the introduction of an nutriment, whether solid or fluid, into the stomach, having becom perfectly impracticable), an attempt was made to prolong his existenc by the exhibition of nutritive enemata, and by immersion of the body night and morning, in a bath of milk and water. During the continuan of this plan, his weight, which had previously been rapidly diminishing remained stationary, although the quantity of the excretions was in creased. How much of the absorption, which must have been effecte to replace the amount of excreted fluid, is to be attributed to the bath and how much to the enemata, it is not easy to say; but it is importan to remark that "the thirst, which was troublesome during the first day of the patient's abstinence, was abated, and, as he declared, removed by the tepid bath, in which he had the most grateful sensations." "I cannot be doubted," Dr. Currie observes, "that the discharge by stoo and perspiration exceeded the weight of the clysters;" and the loss by the urinary excretion, which increased from 24 oz. to 36 oz. under thi system, is only to be accounted-for by the cutaneous absorption.‡—Dr. S. Smith mentions that a man, who had lost nearly 3 lbs. by perspiration during an hour and a quarter's labour in a very hot atmosphere, regaine 8 oz. by immersion in a warm bath at 95°, for half an hour.§ The

* We have a remarkable exception to this general statement, however, in the case of Frogs and other Batrachia, which are characterized by the softness of their skins and the thinness of their epidermic covering; for cutaneous absorption seems in them to be no less active than their cutaneous exhalation and respiration are well known to be. Thus Frogs, which habitually live in a moist atmosphere, seldom or never drink; yet when they have lost fluid by exposure to hot dry air, they will regain their weight by being left for a time upon moist sand; and the bladder, which serves as a reservoir of water for cutaneous exhalation, though previously emptied, will be refilled.

† See a collection of such cases in Dr. Madden's "Experimental Enquiry into the Physiology of Cutaneous Absorption," p. 47.

‡ "Medical Reports," vol. i. pp. 308—326. § "Philosophy of Health," vol. ii. p. 396.

excretions over the fluid ingesta could not have been less than 4 lbs.; making 140 lbs. for the thirty-five days during which the complaint lasted. If from this we deduct the amount of diminution which the weight of the body sustained during the time, we shall still have 113 lbs. to be accounted for, which can only have entered the body from the atmosphere.—A case of ovarian dropsy has been recorded by Mr. Ford,* in which it was observed that the patient, during eighteen days, drank 692 oz. or 43 pints of fluid, and that she discharged by urine and by paracentesis 1298 oz. or 91 pints, which leaves a balance of 606 oz. or 38 pints, to be similarly accounted for.†

130. Not only water, but substances dissolved in it, may be thus introduced. It has been found that, after bathing in infusions of madder, rhubarb, and turmeric, the urine was tinged with these substances; and that a garlic plaster affected the breath, when every care was taken, by breathing through a tube connected with the exterior of the apartment, that the odour should not be received into the lungs.‡ Gallic acid has been found in the urine, after the external application of a decoction of a bark containing it; and the soothing influence, in cases of neuralgic pain, of the external application of cherry-laurel water, is well known. Many saline substances are absorbed by the skin, when applied to it in solution; and it is interesting to remark, that, contrary to what happens in regard to the absorption of these from the alimentary canal, they are for the most part more readily discoverable in the Absorbents than in the Veins. This is probably due to the fact, that the imbibition of them takes place entirely according to physical laws; in conformity with which they pass most readily into the vessels which present the thinnest walls and the largest surface. In the intestines, the vascular plexus on each villus is not only very extensive, but also ensheaths the lacteal trunk; and as the walls of the veins are thin, there is considerable facility for the entrance of saline and other substances into the general current of the circulation: but in the skin, the lymphatics are distributed much more minutely and extensively than the veins, and soluble matters, therefore, enter them in preference to the veins. The absorbent power of the Lymphatics of the skin is well shown by the following experiments. A bandage having been tied by Schreger round the hind-leg of a puppy, the limb was kept for twenty-four hours in tepid milk; at the expiration of this period, the lymphatics were found full of milk, whilst the veins contained none. In repeating this experiment upon a young man, no milk could be detected in the blood drawn from a vein. It has been shown by Muller that, when the posterior extremities of a frog were kept for two hours in a solution of prussiate of potass, the salt had freely penetrated the lymphatics, but had not entered the veins.—It does not follow, however, from these and similar experiments, that in all tissues the lymphatics absorb more readily than the veins; for as the capillary blood-vessels in the Lungs are much more freely exposed to the surface of the air-cells

* "Medical Communications," vol. ii. p. 130.

† In this case, however, as in others of a similar kind, something is to be allowed for the quantity of water contained in the solid food ingested; but this may be fairly considered not to exceed the quantity lost by pulmonary and cutaneous exhalation, and discharged in the fæcal evacuations.

‡ Prof. Dunglison's "Human Physiology," 7th edit. vol. i. p. 688.

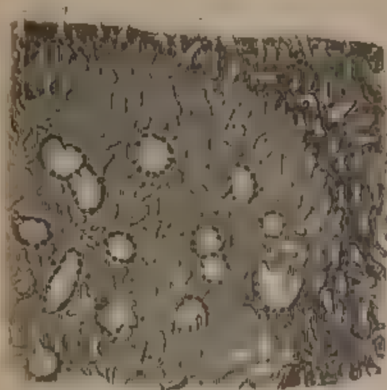
reason why an animal should not derive support from its own dead pa than from the dead body of another individual. Whilst, therefore matter which has undergone too complete a disintegration to be ag employed as nutrient material, is carried-off by the excreting proce that portion which is capable of being again assimilated, may be tak up by the Lymphatic system. If this be the case, we may say with Prout, that "a sort of digestion is carried on in all parts of the body." It may be stated, then, as a general proposition, that the function of t Absorbent System is to take-up, and to convey into the Circulati apparatus, such substances as are capable of appropriation to the *nutrit* process, whether these substances be directly furnished by the extern world, or be derived from the disintegration of the organism itself We have seen that, in the Lacteals, the selecting power is such, that the vessels are not disposed to convey into the system any substances b such as are destined for this purpose; and that extraneous matters a absorbed in preference by the mesenteric Blood-vessels. The case different, however, with regard to the Lymphatics; for there is reason believe that they are more disposed than the venous capillaries, to th absorption of other soluble matters, especially when these are brough into relation with the Skin, through which the lymphatic vessels a very profusely distributed.

3.—*Of the Elaboration of the Nutrient Materials.—Sanguification.*

132. The alimentary substances, taken-up by the Blood-vessels an Absorbents, seem very far from being capable of immediate applicatio to the nutrition of the body; for we find that they are not conveyed b any means directly into the circulating current, but that those which ente the Gastro-intestinal veins are submitted to the operation of the Liver whilst those which are received into the Lacteals are subjected to a kind of glandular action within their own system; the newly absorbed mate rials in both cases undergoing considerable changes, which tend to assi milate them to the components of the Blood.—It will be recollected that all the veins which return the blood from the capillaries of the gastro intestinal canal, converge into the *portal* trunk, which distributes this blood, charged with the newly-absorbed materials, through the capillary system of the *Liver*. The agency of this gland was formerly supposed to be limited to the elimination, from the blood subjected to its influence, of the materials of the biliary secretion; but there is now evidence that the blood itself is changed by its means, in a manner which indicates an *assimilating* as well as a *depurating* action. The blood which comes to the Liver from the alimentary canal, is charged with albuminous matter in a state different from that of the albumen of perfect blood (§ 183); and the assimilation of this would appear, from the observations and experiments of M. Cl. Bernard (§ 185), to be one of the most important functions of the liver. For he found that whilst a solution of egg-albumen, injected into the jugular vein, speedily occasioned a transudation of albumen into the urine, no such transudation occurred when a similar solution was injected into the vena portæ; so that the albumen must have undergone some change in passing through the Liver, which rendered it no longer a foreign ingredient in the blood. So, again, the saccharine matters which are brought to the Liver in the condition of grape sugar or

which joins the mesentery. Each 'Peyerian gland,' in a healthy muco membrane, presents the appe ance of a circular white, slightly raised spot, about a line in di meter, over which the me brane is usually less beset wi villi, and is very often entire destitute of them, and it is su rounded by a ring of opening which are the orifices of a s of caecal follicles disposed in zone around it (Fig 21). Th 'Peyerian patches' (Fig 22) pr sent aggregations of these spot varying in number from tw upwards, but every one of the individual components havin precisely the same structure a the solitary gland. This appear from the recent researches o Brucke, Kolliker, and other not to be (as formerly supposed) a proper gland-vesicle whose contents are surrounded by a limitary membrane; but to be a sort of capsule, whose walls are composed of in distinctly fibrillated con nective tissue with in terspersed nuclei, and whose contents are thus but imperfectly differentiated from the tissues in which the gland is imbedded. These contents are made-up of a granular 'plasma,' containing fatty and albuminous molecules of various sizes, with nuclear particles, and a few cells (Fig. 23); altogether presenting an appearance of being the seat of rapid changes of progressive metamorphosis. Each capsule is surrounded by a close vascular network; and according to the observations of Frei, which have been confirmed by Kolliker,* capillary vessels pass freely into the midst of its contents, and then return by loops, as shown in Fig 24. That these bodies are appendages to the Lacteal system, appears not only from their peculiar position,

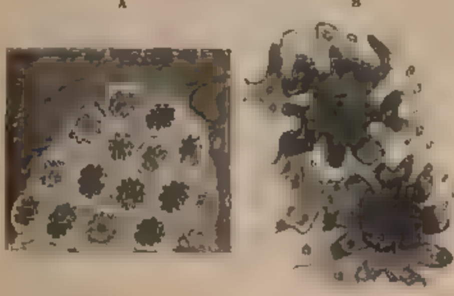
FIG. 21.



Portion of the mucous surface of the end of the Human Ileum, moderately magnified, showing the *Peyerian Glands*, the orifices of the follicles, and the villi.

FIG. 22.

A B



A, Portion of a patch of *Peyerian Glandulæ* from the Ileum of the Pig, as seen from the deep surface, the serous, muscular, and areolar coats having been dissected off, the darker vesicles are open and empty, the paler closed and full, magnified 3 diameters. B, two of these vesicles, viewed from the inner surface of the intestine, one of them closed and full, the other open and empty, with villi and apertures of mucous follicles in their neighbourhood, magnified 15 diameters.

* "Mikroskopische Anatomie," band ii., § 171

tigations of Brücke (loc. cit.), Kolliker,* and others, each absorbent gland is enclosed by a sheath or capsule of fibrous tissue, which sends inwards a large number of thin lamellæ, so disposed and connected together, as to constitute a tolerably regular areolated framework pervading the entire gland (Fig. 25, A). The rounded 'alveoli' thus formed (Fig. 25, B),

Fig. 25.

A B

Section of *Lymphatic Gland*, showing *a a*, the fibrous tissue which forms its exterior; *b b*, superficial vasa inferentia; *c c*, larger alveoli near the surface; *d d*, smaller alveoli of the interior; *e e*, fibrous walls of the alveoli.

Section of one of the alveoli of a Lymphatic Gland; *a a*, its fibrous envelope; *b b*, prolongations from this, intersecting and subdividing the general cavity; *c c*, nuclei of the fibre-cells; *d*, separate fibre-cells.

are filled with a greyish-white pulp, which agrees in all its characters with that of the Peyerian bodies, and which is penetrated, like the latter, by a fine capillary plexus. These 'alveoli' seem to be in free communication both with the *vasa afferentia* and the *vasa efferentia*; and the fluid brought to the glands by the former, must traverse their pulp, before finding its way into the latter. The large increase which is observable in the corpuscles floating in the chyle of the efferent lacteals, as compared with that of the afferent, and the close resemblance which they bear to the corpuscles of the mesenteric glands, leaves it scarcely doubtful that they are partly derived from those bodies. Neither the Absorbent nor the Peyerian glands, however, are to be regarded in any

Wiener Akad.," Dec. 1852, Jan. 1853, and March, 1853. See also Brüch, in "Siebold and Kölliker's Zeitschrift," April, 1853. Their results appear to prove quite conclusively, that the Peyerian glandulæ are really appendages to the Absorbent system, corresponding in every respect, save their situation, to the mesenteric and lymphatic glands; and hence that their open or follicular condition, which has been so frequently met with as to have been regarded by Profs. Krause and Allen Thomson as a normal stage in their history (see especially the Memoir by the latter in "Goodsir's Annals of Anatomy and Physiology," No. 1), has not the signification formerly attached to it. In Dr. A. Thomson's observations, which were chiefly made on the Pig, some patches presented no openings, in others almost all the vesicles were open and empty, while in a third set open and closed vesicles were found irregularly mingled in the same patch (Figs. 22, 23); and the Author has himself frequently met with the follicles in the open condition, in cases in which there was no appearance of disease. It remains as a point for inquiry, therefore, whether there is not a continual dying away and new production of these bodies; a hypothesis which would in some degree account for the remarkable variety in their number and seat, which presents itself in different individuals.

* "Mikroskopische Anatomie," band ii. § 250.

from those of the fluid first absorbed into the Lacteals; for durin passage through these vessels and the Mesenteric glands, it unde important alterations, which gradually assimilate it to Blood. The c drawn from the lacteals that traverse the intestinal walls, contains A men in a state of complete solution; but it is generally destitute of power of coagulation, no Fibrine being present in it. The Salts, are completely dissolved; but the Oily matter presents itself in the of globules of variable size.* It is generally supposed, that the m colour of the chyle is owing to these; but Mr. Gulliver has pointed that it is really due to an immense multitude of far more minute ticles, which he describes as forming the *molecular base* of the ch These molecules are most abundant in rich, milky, opaque chyle, wh in poorer chyle, which is semi transparent, or opaline, the particles thinly or separately in the transparent fluid, and often exhibit the v motions common to the most minute molecules of various substan Such is their minuteness, that, even with the best instruments, it is possible to form an exact appreciation either of their form or th dimensions. They seem, however, to be generally spherical, and th diameter may be estimated at between 1-36,000th and 1-24,000th of inch. Though remarkable for their unchangeableness, when subjected the action of numerous re-agents which quickly affect the proper Ch corpuscles, they are readily soluble in ether, the addition of which ca the whole molecular base instantly to disappear, not a particle of remaining; whence it may be inferred that they consist of oily or fa matter. That they do not ordinarily tend to coalesce, is probably due the coating of albumen which they obtain through their diffusion in albuminous fluid; if, however, this be dissolved by acetic acid, or even the addition of water, many of the molecules are lost-sight-of, and o drops appear in their place. The milky colour which the Serum of blo sometimes exhibits in healthy subjects (§ 177), is due to an admixture this molecular base with the circulating fluid.

136 During the passage of the Chyle through the absorbents on th intestinal edge of the mesentery, towards the Mesenteric Glands, its ch racter changes in several important particulars. The presence of Fib begins to manifest itself, by the slight coagulability of the fluid wh withdrawn from the vessels; and a few Chyle corpuscles make the appearance. The diameter of these bodies varies from 1-7110th 1-2600th of an inch: the average being about 1-4600th. The smalle among them (Fig. 26, *b*, *c*) seem to be in the condition of nuclei, in tho a little larger, (*d*, *e*) the cell wall is beginning to be differentiated fro the nucleus; whilst in those of greatest diameter (*f*, *g*, *h*, *i*), the cellul character is very distinct, and the nucleus may be plainly seen in th interior, especially after the addition of a little water or acetic aci They occasionally exhibit curious changes of form (*a*, *a*); in this respe corresponding with the Colourless corpuscles of the blood (§ 164), whi are probably the same bodies in a more advanced stage. A great increa

* These oily globules are more abundant in the Chyle of Man and of the Carn than in that of the Herbivora; their diameter has been observed to vary from 1-25,00 to 1 2000th of an inch.

† "Gerber's General Anatomy," Appendix, p. 88; and "Hewson's Works" (Syde ham Society's Edition), notes to pp. 82-88

other instances none can be discovered. Lymph coagulates like chyle; a colourless clot being formed, which incloses the greater part of the corpuscles.

138. The fluid drawn from the Thoracic Duct, consisting as it does of an admixture of Chyle and Lymph, will probably vary in its character and composition, according to the predominance of the former, or of the latter, of these constituents.—From the observations made by Bidder and Schmidt,* on the quantity of fluid discharged from the thoracic ducts of dogs and cats immediately after death, it is inferred by them that the total amount of mingled lymph and chyle which is daily poured into the Subclavian vein of Man, is no less than 28¾ lbs., or fully as much as the entire mass of the blood,—its solid constituents, however, being not more than from one-fourth to one-third the amount contained in the blood. Of the whole quantity thus discharged, it is estimated that only about 6½ lbs. would be Chyle derived from ingested aliment, the remainder being Lymph, which has passed out of the blood-current in the course of its circulation, only to be returned to it again.

139. The movement of the fluids taken-up by the Absorbent vessels, seems to depend upon a combination of different agencies. The lower Vertebrata are provided with 'lymphatic hearts,' or pulsatile cavities, by which important assistance is given in the onward flow; but no such aid is afforded in Man or in the Mammalia; yet it is obvious that a considerable *vis a tergo* must exist, since, if the thoracic duct be tied, it is speedily distended below the ligature, even to bursting. The Absorbent vessels, like the veins, have a fibrous coat, into which the muscular fibre-cells enter largely, and which is therefore contractile; and it has been found by Prof. Kolliker, that when the wire of an electro-magnetic apparatus was applied to some well-filled lymphatics on the skin of a boy's foot, soon after the removal of the leg by amputation, the stimulus occasioned a diminution in their diameter by at least one-half, and this not suddenly, but in the course of between half a minute and a minute.† The same excellent anatomist has observed that the lymphatic vessels in the tail of a Tadpole empty themselves by contraction after death, and then dilate again to their former size, just as the smaller arteries do under the like circumstances;‡ and this fact is in accordance with the emptiness of the Absorbent system, which usually presents itself in Man some little time after death. Hence it seems probable that a regular propulsion of their contents during life, may be effected by alternate contractions and dilatations of successive portions of the vessels, slowly repeated at intervals.§—There are, however, certain auxiliary forces. For, in the first place, a part of the movement may be attributed to the *vis a tergo*, which is produced by the continual introduction of fresh fluid into the

* "Verdauungs-safte und Stoffwechsel," §§ 224, 285.

† "Kolliker and Siebold's Zeitschrift," 1849.

‡ "Annales des Sciences Naturelles," 3ième Sér., Zool., tom. vi. p. 99.

§ A regular rhythmical movement of the *veins* of the Bat's wing, obviously sustained by their independent contractility, has been observed by Mr. Wharton Jones ("Philosophical Transactions," 1852, p. 131). The existence of such a movement in the Veins of a part, as an auxiliary propulsive force, obviously strengthens the probability of its occurrence in the Lymphatics, as the principal propelling power, where no central impulsive organ exists; just as a like movement is seen in the blood-vessels of such of the lower Invertebrata as have no heart.

lating current any substances which they may withdraw from it; and there seems adequate ground, therefore, for the conclusion, that their action, whatever it may be, is subsidiary to the completion of the process of Sanguification,—being exercised, perhaps, upon that portion of the nutrient materials more especially, which did not traverse the Absorbent system when first introduced, but which was directly taken-up by the Blood-vessels. The organs in question are the Spleen, and the Thymus, Thyroid, and Supra-renal bodies. Of these, the Spleen deserves especial notice, on account of its size and its obvious functional importance in the adult; the others appearing to minister more particularly to the requirements of the system at the earlier periods of life.

142. The minute structure of the *Spleen* has recently been made the subject of careful research by many excellent Microscopic observers: more especially by Prof. Kolliker,* Dr. Sanders,† Mr. Wharton Jones,‡ Mr. Huxley,§ and Mr. Gray; ‖ and, for the lower Vertebrata in particular, by Remak,¶ and Leydig.** The following are the most important points which may be considered to have been established by their labours.

I. The *fibrous coat* in Man is composed of white fibrous tissue, with an intermixture of yellow or elastic fibres; in many of the lower animals, however, it contains non-striated muscular fibres, composed of fusiform fibre-cells. The *trabecular tissue* consists of bands and threads of fibrous tissue, which arise from the inner surface of the fibrous envelope, and form a network that extends through the entire organ, becoming connected also with the fibrous sheaths of the vessels which penetrate it. These bands are partly muscular in the animals which have muscular fibres in the external envelope; but elsewhere they are simply fibrous. The spaces left by their intersection, which are by no means regular as to either form or size, are occupied by the splenic corpuscles and splenic parenchyma.

II. Of the *Arteries* of the Spleen, it is chiefly to be observed that their branches form no anastomoses, but subdivide and ramify like the branches of a tree, with the Malpighian corpuscles attached to them as fruit (Fig. 27). Beyond their connection with these, however, they enter the general mass of the splenic parenchyma; and here each twig subdivides into a tuft of arterioles still more minute, which again subdivide into the true capillaries.—The *Capillaries*, bounded only by their very thin walls, pass in every direction through the spleen-pulp, both in the general mass of the organ, and also in the interior of the Malpighian corpuscles. But it is affirmed by Mr. Gray, that in the Spleen of Man and of many other animals, the walls of the capillaries frequently dis-

* "Cyclopedia of Anatomy and Physiology," vol. iv., Art. 'Spleen;' and "Mikroskopische Anatomie," band ii. §§ 183–189.

† "Goodsir's Annals of Anatomy and Physiology," No. 1., and "Edinb. Monthly Journal," March, 1852, p. 286.

‡ "Brit. and For. Med. Chir. Review," vol. xi. p. 32.

§ "Quarterly Journal of Microscopical Science," vol. ii. p. 74; and Translation of Kolliker's "Manual of Human Histology" (Sydenham Society), vol. ii. p. 144.

‖ "On the Structure and Use of the Spleen" (Astley-Cooper Prize Essay, 1854).

¶ 'Ueber runde Blut-gerinnsel und über Pigment-kugelhaltige Zellen,' in "Müller's Archiv.," 1852.

** "Anatomische-Histologische Untersuchungen uber Fische und Reptilien," 1853.

greatest in healthy well-fed animals, whilst in those that have be[illegible] fed they diminish extremely, and in those that have been starved disappear altogether. Hence it has happened that their existence i[illegible] Human species has been denied, the opportunity of examining sub[illegible] not reduced by previous abstinence, being one that comparatively se[illegible] occurs. There is no doubt, however, of their normal presence in spleen of Man, as in that of other Mammalia.—Diffused amidst colourless parenchyma, but in very variable amount, *coloured* cell[illegible] found, some of which are unchanged blood-corpuscles, whilst o[illegible] appear to be blood-discs in various stages of retrograde metamorph[illegible] gradually diminishing in size, and assuming a golden-yellow, brow[illegible] red, or even blackish colour, or having the pigmentary matter crystal[illegible] in a rod-like form in their interior (Fig. 38); or, again, breaking-up [illegible] detached pigment-granules. Occasionally (though very rarely in Human subject) little clusters of these degenerating blood-corpuscle[illegible] found, included in a vesicular envelope. All these bodies are see[illegible] the blood of the Splenic vein; and it has been hence concluded by s[illegible] that they do not constitute normal elements of the Splenic parench[illegible] but that they are either contained in its capillaries, or, if actually diff[illegible] through the pulp, are so as a result of an abnormal extravasation. T[illegible] conflicting views may be reconciled, if, as stated by Mr. Gray, the spl[illegible] blood, in its passage from the arteries to the veins, normally esc[illegible] from the walled vessels into indefinite channels, so that its corpus[illegible] may become diffused through the parenchyma without any departure f[illegible] its regular course, and it is a confirmation of this view, that [illegible] amount of *coloured* corpuscles in the spleen-pulp augments with [illegible] general turgescence of the vascular system, and diminishes with [illegible] poverty of the blood, so that, in animals reduced by ill feeding, it dis[illegible] pears altogether.*

IV. The *Lymphatics* of the Spleen are few and inconsiderable in M[illegible] being less numerous than in other glandular organs, such as the liver [illegible] kidneys. In some of the lower animals, they are more abundant; [illegible] even here they are mostly superficial, and scarcely penetrate to the inte[illegible] of the organ.

V. The *Nerves* of the Spleen are apparently very large in some anim[illegible] especially in the Ruminants; but the great size of their trunks a[illegible] branches is chiefly due to the large proportion of ordinary fibrous tis[illegible] which enters them; the number of real nerve-fibres being extrem[illegible] small.†

* That the coloured portion of the spleen-pulp consists entirely of red blood corpus[illegible] in various stages of degeneration, is a doctrine first advanced by Kolliker, and [illegible] more especially by Gray. On the other hand, it is maintained by Remak that [illegible] coloured corpuscles are true pigment-cells, having no relation to blood-discs, but a toge[illegible] *sui generis*. The extended enquiries of Mr. Gray, who has traced the metamorphic p[illegible] in a great variety of animals, seem to the Author to leave little doubt of the correctn[illegible] of the former view, though proper pigment-cells may also exist; and it is an interest[illegible] confirmation of Mr. G.'s account of the mode of derivation of the coloured elements fr[illegible] the blood circulating through the spleen-pulp, that in those animals in which he traces [illegible] capillary network in the substance of the spleen to be *closed* throughout, there are [illegible] *coloured corpuscles* in the parenchyma.

† A comprehensive view of the essential nature of the Spleen, based upon the variet[illegible] of structure which it presents in different animals, shews that, as Remak urges, we s[illegible] regard it as formed of two principal constituents, the first being its parenchymatous el[illegible]

leave a series of oval spaces, lying end to end;* which spaces are fil[led] with a finely-granular plasma, containing a large amount of fat-partic[les] with nuclear corpuscles, and more or less completely-formed ce[lls]. Isolated cells of a larger size are found in the stroma of the inner p[art] of the cortex, in which the linearly-arranged spaces do not exist.—T[he] *medullary* substance consists of a basis of fibrous tissue, which is form[ed] by processes that come-off from the sheath of the cortical substance, a[nd] which contains numerous blood vessels and nerves. The interspaces of th[is] tissue, however, are occupied by a granular plasma, in which are nuc[lei] and cells in various stages of development; and the recent observatio[ns] of Kolliker upon the nature of these cells, which are confirmed by th[e] researches of Leydig (Op. cit.) upon the corresponding organs in th[e] Amphibia, seem to indicate that they are really *ganglionic* in their cha[racter]. It had been previously remarked that the Medullary substan[ce] receives a peculiarly large supply of nerves from the Sympathet[ic] system, and it thus appears as if this portion of the organ is but little [or] not at all related in function to that which invests it, but is really [a] peculiar Sympathetic ganglion.† Both the cortical and the medulla[ry] substances receive a large supply of blood, which is distributed throug[h] a minutely-divided capillary plexus; its meshes being elongated in th[e] former, and more rounded in the latter

145. The *development* of the Supra-Renal bodies also has been studie[d] by Mr. Gray (loc. cit.). He states that they arise on the 7th day o[f] incubation, as two separate masses of blastema, situated between th[e] upper end of the Wolffian bodies and the sides of the aorta; being totall[y] independent (as concerns their development) of those bodies and of eac[h] other. At this period, their minute structure bears a close resemblanc[e] to that of the spleen, consisting of the same elements as that gland excepting in the existence of more numerous dark granules, which giv[e] to the organ at a later period an opake and darkly-granular texture and the general history follows a very similar course, the Supra-renal capsules, however, acquiring their characteristic structure, and attaining their largest relative size, so early in fœtal life, as to surpass the Kidneys in dimension up to the tenth or twelfth week of Human embryonic development; though they afterwards diminish so much, relatively to the Kidneys, as to possess in the adult condition only 1-28th part of their bulk.

146 The general structure of the *Thymus* Gland may be best understood from the simple form it presents, when it is first capable of being distinguished in the embryo. It then consists of a single tube closed at *both* ends, and filled with granular matter; and its subsequent development consists in the lateral growth of branching off-shoots from

* This is the account given by Kölliker ("Mikroskopische Anatomie," § 220), who con[fidently] states that the spaces are not bounded by a proper limitary membrane and are therefore not gland-vesicles as supposed by Ecker and Frey, whose views of their nature will be found in the Art. 'Supra-Renal Capsules' in the "Cyclop. of Anat. and Physiol," vol. iv.

† A curious observation, strikingly confirmatory of this view of the peculiar relation of the Medullary substance to the Nervous System, has been recently made by M. Brown Séquard; viz., that injuries to the Spinal Cord in the dorsal region, produce congestion and (after a time) hypertrophy of the Supra-Renal capsules ("Gazette Medicale, Fevr 1, 1852).

and form a close reticulation in the delicate pellicle of connective tissue with which it is lined; from the several points at which the lobular cavities open, numerous vessels arise from this plexus (Fig. 30), passing along their internal surface; and from these is derived the capillary plexus which traverses the substance of each gland granule, but which does not pass as far as its external surface, returning by loops before it reaches its fibrous envelope. The Lymphatics of the Thymus are large, and communicate directly with the Vena Cava; but their immediate connection with the cavity of the Thymus body has not been demonstrated.—It has been commonly stated, that the Thymus attains its greatest development, in relation to the rest of the body, during the latter part of fœtal life; and it has been considered as an organ peculiarly connected with the embryonic condition. But this is a mistake; for the greatest activity in the growth of this organ manifests itself, in the Human infant, soon after birth; and it is then, too, that its functional energy seems the highest. This rapid state of growth, however, soon subsides into one of less activity, which merely serves to keep up its proportion to the rest of the body; and its increase usually ceases altogether at the age of about two years. From that time, during a variable number of years, it remains stationary in point of size; but, if the individual be adequately nourished, it gradually assumes the character of a mass of fat, by the development of the corpuscles of its interior into fat-cells, which secrete adipose matter for the blood. This change in its function is most remarkable in hybernating Mammals; in which the development of the organ continues, even in an increasing ratio, until the animal reaches adult age when it includes a large quantity of fatty matter. The same is the case, generally speaking, among Reptiles.

Fig. 30.

Transverse section through an injected lobule of the *Thymus* in a child:—*a*, membranous investment of the lobule; *b*, membranes of the gland granules; *c*, cavity of the lobule, from which the larger vessels branch out.

147. The *Thyroid* body differs from the other Vascular Glands in its elementary structure; for it essentially consists of an aggregation of closed vesicles (Fig. 31, *b,b*), which seem to be furnished with a true limitary membrane, and therefore to be real gland-vesicles, imbedded in a stroma (*a, a*) of connective tissue, and not communicating with any common reservoir. These bodies vary in diameter, in the Human subject, from 1-2000th to 1-85th of an inch; and they contain an albuminoid plasma,* which is either faintly granular, or of a somewhat oily aspect, amidst which are seen a number of corpuscles, the greater part of them in the condition of nuclei, whilst some have advanced to that of cells. These

* That the fluid does *not* contain true Albumen in solution, but some albuminous compounds, is indicated by the results of Dr. Beale's analysis ("Cyclop. of Anat. and Physiol.," vol. iv. p. 1106.)

serve some special purpose in the economy, appears from the fact that they are not carried-off by ducts, but are received again into the current of the circulation. With the exception of the Spleen, all the ductless glands thus discharge their products at once into the general venous circulation; so that, after having passed through the lungs, they will be carried by the systemic arteries through the system at large: but the splenic vein, it will be remembered, forms one of the roots of the portal trunk; and *its* blood must thus pass through the *liver*, before it enters the vena cava. For this exception, a reason may probably be found in the peculiar offices which this organ seems to perform (§ 151).

149. Whatever materials, then, are withdrawn from the Blood by these organs, are returned to it again in an altered state, and it may fairly be inferred from this circumstance, that the change which they have undergone is one that prepares them for higher uses in the economy. For as the blood which has received them is immediately transmitted to the system (except in the case of the splenic blood), without having passed through any other depurating organ than the lungs, it appears fair to conclude that the products which it has taken up in these organs are either *combustive* or *nutritive*, *i. e.*, either serve to maintain the functional activity of the lungs, or of the system, or of the blood itself. Now that they are not destined to prepare a pabulum for respiration, appears from the very small quantity of fat which is found in their substance, except when their period of functional activity has gone-by. On the other hand, the albuminous nature of the plasma, and the finely-granular appearance which it presents, strongly indicate that a material is here in progress of preparation, which is to be rendered subservient to the formative operations. Various facts which have been noticed in regard to the changes in the bulk of the Thymus in young animals (and particularly its rapid diminution in over-driven lambs, and its subsequent gradual re-distension during rest, if plentiful nutriment be afforded), lead to the conclusion that such is almost undoubtedly the function of that body. And such would also seem to be the justifiable inference from the researches of Mr. Gray on the Spleen: for the correspondence in the amount of the colourless parenchyma of that organ (and especially of its Malpighian corpuscles) with the general state of nutrition of the animal, its regular increase (in well-fed animals) near the completion of the digestive process, and its gradual diminution in the subsequent interval, seem to indicate that the Spleen, like the Thymus of the young animal, is a storehouse of nutritive material, which may be drawn-upon according to the requirements of the system, just as the fat of the body is a storehouse of combustive substance. And of the exertion of an elaborating or assimilative action upon this albuminous matter, during its withdrawal from the current of the circulation in these organs, we seem to have direct evidence, as regards the Spleen, in the large increase of the proportion of fibrin contained in the blood drawn from its veins (§ 181).

150. But further, it does not seem at all unreasonable to suppose that these organs may be concerned, equally with the Absorbent glands, in supplying the germs of those cells which are ultimately to become Blood corpuscles. Such, it is well known, was the doctrine of Hewson* in

* See his Third Series of "Experimental Inquiries," Chaps. iii.-v.

evident that turgescence of the portal system is liable to occur, when the alimentary canal is distended with food and this from two causes,—the pressure on the intestinal veins, and the quantity of fluid absorbed by these veins. Hence it may be conceived, that the Spleen, by affording a reservoir into which the superfluous blood may be directed, serves an important purpose in preventing congestion of other organs. From the observations of Mr. Dobson,* it appears that the Spleen has its maximum volume at the time when the process of chymification is at an end,—namely, about five hours after food is taken; and that it is small and contains little blood seven hours later, when no food has been taken in the interval. Hence he inferred that this organ is the receptacle for the increased quantity of blood, which the system acquires from the food, and which cannot, without danger, be admitted into the blood-vessels generally; and that it regains its previous dimensions, after the volume of the circulating fluid has been reduced by secretion. This view is confirmed by the fact noticed by several observers,—that the Spleen rapidly increases in bulk after the ingestion of a large quantity of fluid, which is absorbed rather by the Veins than by the Lacteals. It has been further stated in support of this theory, that animals from which the Spleen has been removed, are very liable to die of apoplexy, if they take a large quantity of food at a time; but that, if they eat moderately and frequently, they do not suffer in this manner.—Now this doctrine derives its chief support from experiments on Ruminating and other Herbivorous animals, whose food is very bulky, and who ingest a large quantity of it at a time; and it is in them that the organ is most distensible, and that the splenic vein is best adapted, by the peculiar disposition of its coats, for the reception of a very large amount of blood. The *cellated* structure which forms a large part of the spleen in these tribes, is almost wanting in Man (§ 142, II.); and the fibrous envelope of his spleen, with its trabecular partitions, has very little either of elasticity or contractility. Nevertheless, there is evidence that an extraordinary accumulation of blood may take place in this organ, even in him, from any cause which obstructs the passage of blood through the liver, or which impedes its return to the heart (as in Asphyxia, § 327), or which occasions a general internal venous congestion, such as occurs in the cold stage of intermittent fever. The peculiar liability of the Spleen to be distended with blood in this last condition, is shown by its permanent enlargement in those who have been long the subjects of such complaints.—Thus it appears that the Spleen may serve, independently of its primary function, as a sort of safety-valve to the portal circulation; and that its structure is most particularly adapted for such a purpose in those tribes of animals, which, from their habits of feeding, may be considered most specially to need an organization of this kind.

152. There is strong evidence, moreover, that the Spleen of Man, as of a large proportion of Vertebrated animals, performs another function connected with the regulation of the composition of the Blood; namely, that it promotes, under certain circumstances, the disintegration of the Red Corpuscles. If it be true that the *coloured* portion of the pulp consists entirely (as affirmed by Kolliker and Gray) of red blood corpuscles in various stages of degeneration, which have escaped from the channels

* "London Medical and Physical Journal," October, 1820

or suspension of the eliminating operations.—But besides thus me the demand occasioned by the *constructive* operations, and preventing results of the *destructive* from exerting an injurious influence on system, the Blood acts (so to speak) as the carrier of Oxygen introd from the atmosphere, to the Muscular and Nervous tissues, to w peculiar vital activity its presence appears to be an essential condi the same element being also required in various other metamorph which form part both of the constructive and of the destructive operati whilst conversely it imbibes the Carbonic acid, which is one of the products of the action of oxygen upon the tissues and fluids of the b and conveys this to the lungs and skin for elimination. This produ continually being formed in such large amount, that its presence in the bl can always be readily demonstrated; and if its elimination be chec for even a few minutes, it accumulates to such an extent as to occa the immediate destruction of life.—But in addition to the Histogen materials and Oxygen, on the one hand, and the various products of disintegration of the tissues on the other, the blood contains those n azotized substances, which are received into it for the purpose of supply the *pabulum* of the Combustive process; and the union of their car with oxygen introduced from the atmosphere, which is continually go on, becomes an additional source of the production of carbonic acid, of its injurious accumulation if its elimination be checked.

154. From this variety in the operations to which the Blood is s servient, it naturally follows that the changes which it undergoes different parts of its circulation are of a very diversified nature, and t the composition of the fluid in the several parts of its course will be from uniform. Between the blood which is being distributed by systemic Arteries to the body at large, and that which is being collec from it again by the systemic Veins, after having percolated the tissu there is not only an obvious difference in hue, which indicates an imp tant change, but there is also a considerable difference in compositio which is revealed by chemical analysis: and a difference of a conve nature presents itself, between the blood that is on its way to be dist buted to the Lungs, and that which is returning from them. So, agai although there is no obvious dissimilarity in physical characters, betwe the blood which is transmitted to the Liver by the vena portæ, and th which is carried-off from it by the hepatic vein, yet chemical analysis r veals a very remarkable difference in their composition, and shows th the blood of the ascending vena cava (above the entrance of the hepat vein), that of the right cavities of the heart, and that of the pulmona artery, differs from all other blood in the body, in containing a appreciable quantity of that peculiar sugar which is formed in its passag through the Liver (§ 132). In many other cases, we know th an important difference *must* exist, although chemical analysis has no yet detected it; thus the blood of the Renal vein must be more free fro the components of the urinary excretion, than that of the renal arter which conveys them to the kidney; whilst the blood of the System veins in general must contain them in greater amount than their corre ponding arteries, since they are discharged into the current during it passage through the tissues, of whose disintegration they are among th products.—In the account to be presently given of the Blood, those mo

decapitation. In the first of these cases, it is probable that, as death could not have been *immediate*, some increase took place from the fluids of the body; in the second, however, the suddenness of the discharge of blood, and its concurrence with the destruction of life, must have prevented any considerable augmentation from this source; and if any such increase did take place, it probably did not exceed the amount of blood remaining undischarged in the vessels. In two cases in which the weight of blood which drained from the bodies of decapitated criminals was determined by Profrs. E. Weber and Lehmann (allowance being made for the large quantity of water which mingled with its latter portions), it was found to bear to the weight of the body at large almost exactly the ratio of 1 : 8.* Several circumstances lead to the belief that this estimate is not far from the average; but it cannot be doubted that a considerable variation in the relative amount of blood will exist among different individuals.†

2. *Physical, Chemical, and Structural Characters of the Blood.*

156. The Blood as it flows-forth from an opening in a large vessel, is an apparently homogeneous liquid, possessing a slight degree of viscidity, with a consistence and density somewhat greater than that of water, but especially distinguished by its *colour*, which is usually of a bright scarlet when it is drawn from an artery, and of a dark purple, sometimes almost approaching to black, when it is drawn from a vein. This difference of colour, however, is by no means constant; for arterial blood may sometimes be unusually dark, whilst venous blood is occasionally so florid that it might almost be taken for arterial. The former condition is observable, when from any cause the respiratory process is imperfectly effected, and may be especially noticed during operations performed

* See Prof. Lehmann's "Lehrbuch" (2nd edit.), band ii. p. 234.

† Another mode of determining the total amount of the circulating blood has been proposed by Prof. Valentin ("Repert. für Anat. und Phys.," band iii. p. 281), who first draws a sample of blood from an animal, and ascertains the proportion of water which it contains, then injects a determinate quantity of water into the vessels, and immediately draws fresh samples from different parts of the body, in which also he ascertains the proportion of the solid to the fluid components, and from the amount of dilution which the last-drawn blood exhibits, as compared with the first sample, he calculates the whole bulk of the circulating fluid. From these data, Prof. Valentin estimated the proportion of blood in the Dog as 1 : 4½, and in the Sheep as 1 : 5; so that, applying the former of these proportions to the Human body, a man weighing 145 lbs. would have 32 lbs. of blood, and a woman weighing 127 lbs. would have 27 lbs. of blood. It can scarcely be doubted that this statement is too high; and it is not difficult to discern an important fallacy in the method on which it was based. For however rapidly the operation may be performed, some portion of the water injected will transude from the vessels into the surrounding tissues, and will escape by the kidneys; and thus, the degree of its dilution being diminished, the estimate of the total amount of the blood will be raised considerably above the reality. It has been more recently proposed by more than one experimenter, to inject, in place of water, some saline compound, whose presence in the blood might easily be determined quantitatively, and which should neither be so poisonous as to produce speedy death, nor be capable of such rapid transudation as to escape too readily into the tissues or the urine. The sulphate of alumina has been employed for this purpose by Prof. Blake (of St. Louis, U. S.), and his experiments lead to the conclusion that the proportion of blood in the body of a Dog is as 1 : 8 or 1 : 9; so that, applying the same proportion to Man, the quantity of blood in a Human body weighing 144 lbs. would be 16 or 18 lbs. See Prof. Dunglison's "Human Physiology," seventh edit. vol. ii. p. 102.

Blood; namely, *Fibrin*, *Albumen*, *Corpuscles*, and *Saline matter*. In the *circulating* blood, they are thus combined :—

Fibrin Albumen [redacted]	}	In solution, forming Liquor Sanguinis.
Corpuscles,		suspended in Liquor Sanguinis.

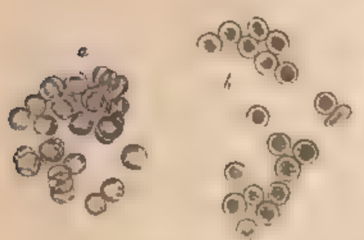
But in *coagulated* blood, they are combined as follows :—

Fibrin Corpuscles	}	Forming Crassamentum, or Clot.
Albumen Salts	}	Remaining in solution, forming Serum.

The change from the one condition to the other is due to the fibrillation of the Fibrin, which usually takes place so speedily, as to involve the Corpuscles floating in the 'liquor sanguinis,' before they have time to subside; although, under various conditions hereafter to be described (§§ 205, 206), it may occur in such a manner, that the clot, or a portion of it, is left colourless.

158. The *Red Corpuscles* of the Blood (commonly, but erroneously termed 'globules') are *cells* of a flattened or discoidal form, which, in Man, as in most of the Mammalia, have a distinctly-circular outline. In the discs of Human blood, when this is examined in its natural condition, the sides are somewhat concave; and there is a bright spot in the centre, which has been regarded by many as indicating the existence of a nucleus; though it is really nothing else than an effect of refraction, and may be exchanged for a dark one by slightly altering the focus of the Microscope (Fig. 32). The form of the disc is very much altered by various reagents; for the membrane which composes its exterior, or cell-wall, is readily permeable by liquids; so as to admit of their passage, according to the laws of Endosmose, either inwards or outwards, as the relative density of the contents of the cell and of the surrounding fluid may direct. Thus, if the Red Corpuscles be treated with water, or with a solution of sugar, albumen, or salt, which is of less density than the liquor sanguinis, there is a passage of this liquid into the cell; the disc first becomes flat, and then double-convex, so that the central spot disappears; and by a continuance of the same process, it at last becomes globular, and finally bursts, the cell wall giving way, and allowing the diffusion of its contents through the surrounding liquid. If, on the other hand, the Red Corpuscles be treated with a thick syrup or with a solution of albumen or of salt, they will be more or less completely emptied, and caused to assume a shrunken appearance; the first effect of the process being to increase the concavity, and to render the central spot more

FIG. 32.



Red Corpuscles of *Human Blood*, represented at *a*, as they are seen when rather beyond the focus of the microscope; and at *b*, as they appear when within the focus.

action of acetic acid, which renders the remainder of the particle extremely transparent, whilst it gives increased opacity to the nucleus, which is then seen to consist of a granular substance (*d*). In the still larger blood disc of the Proteus and Siren, this appearance is yet more distinct.*

159. The *form* of the Red Corpuscles is not unfrequently seen to change during their circulation; but this is generally in consequence of pressure, from the effects of which, however, they quickly recover themselves. In the capillary vessels, they sometimes become suddenly elongated, twisted, or bent, through a narrowing of the channel; and this change may take place to such a degree, as to enable the disc to pass through an aperture which appears very minute in proportion to its diameter. When undergoing spontaneous decomposition, the blood-discs become granulated, and sometimes (as long since noticed by Hewson) even mulberry-shaped; and particles in which these changes appear to be commencing, may be found in the blood at all times.—The *size* of the blood-discs is liable to considerable variation, even in the same individual; some being met-with as much as one-third larger, whilst others are one-third smaller, than the average. The diameter of the corpuscles bears no constant relation to the size of the animal, even within the limits of the same class; thus, although those of the Elephant are the largest among Mammalia (as far as is hitherto known), those of the Mouse tribe are far from being the smallest, being, in fact, more than three times the diameter of those of the Musk Deer. There is, however, as Mr Gulliver has remarked, a more uniform relation between the size of the animal and that of its blood discs, when the comparison is made within the limits of the same order. In Man, their diameter varies from about 1-4000th to 1-2800th of an inch, the average diameter being probably about 1-3200th; and their average thickness, according to the same excellent observer, is about 1-12,400th of an inch.† According to the recent estimates of Vierordt, a cubic centimetre of blood (which is no more than about 6-100ths of a cubic inch) contains no fewer than 5,055,000 red cor-

* See "Penny Cyclopædia," Art. 'Siren.'

† A Tabular summary of Mr. Gulliver's very numerous and accurate measurements of the Red Corpuscles of the Blood of different animals, from all the classes and most of the orders of the Vertebrate series, is contained in the "Proceedings of the Zoological Society," No. cii., and also in his Edition of the "Works of Hewson" already referred to, published by the Sydenham Society (p. 237). From these, the following measurements of the blood of domestic animals (expressed in fractions of an English inch) may be selected, as the most likely to become of interest in Juridical inquiries, in which it is frequently of importance to ascertain the precise source of stains, whose sanguineous character has been determined.

Man	1-3200	Pig	1-4230
Dog	1-3532	Ox	1-4267
Hare	1-3560	Red Deer	1-4324
Rabbit	1-3607	Cat	1-4404
Rat	1-3754	Horse	1-4600
Mouse	1-3814	Sheep	1-5300
Ass	1-4000	Goat	1-6366

Thus it appears quite possible to distinguish the blood of all the animals enumerated, from that of Man, by the measurement of the diameter of the Red Corpuscles; those of the Dog and of the Rodents approaching his most nearly in size, while those of the Ruminant and Pachydermatous quadrupeds, and of the Cat, are considerably smaller. It is important, however, to bear in mind, that the specimens of blood submitted to examination in Juridical inquiries, will for the most part have been dried, and it is

Corpuscles replace the Fibrin and Albumen of the Liquor Sanguinis, but the proportion of Fat in the former is considerably greater than in the latter; and that although the whole amount of mineral matter (excluding the iron of Hæmatin, which would amount to 1·17), is nearly the same in the Corpuscles as in the Liquor Sanguinis, yet that there is a most remarkable and significant difference in its constituents in the two cases respectively. For while the Chlorine of the corpuscles is to that of the liq. sang. as 1 : 2·16, the Phosphoric acid of the corpuscles is to that of the liq. sang. as nearly 6 : 1, and whilst the Sodium of the corpuscles is to that of the liq. sang. as 1 : 3 3, the Potassium of the corpuscles is to that of the liq. sang. as 10·3 to 1. Hence it is obvious that the Chloride of Sodium of the blood must be principally contained within the liquor sanguinis, whilst the Potash of the blood is almost wholly included in the substance of the corpuscles; and from the excess of Phosphorus in the corpuscles, as well as of Fat, it may be fairly concluded, that it is in them that the peculiar 'phosphorized fats' are chiefly formed.—These facts seem to suggest a very important office for the Red Corpuscles, which is in harmony with all we know of the ratio that their amount in different animals, and in different individuals of the Human species, bears to the development of nervo-muscular power (§ 210), namely, that they are especially concerned in preparing the *pabulum* for the Nervous and Muscular tissues, the former of which is distinguished by the presence of phosphorized fats, and the latter by the remarkable predominance of the potash-salts.* And this view derives further confirmation from the fact, that a flesh-diet seems to have a decided effect in promoting the formation of the red corpuscles (§ 177). The Red Corpuscles appear to have a remarkable power of absorbing certain gases; for it has been found by Van Maack and Scherer, that a solution of hæmatin imbibes a considerable amount of oxygen, the latter of these chemists having also ascertained that after the absorption of oxygen there is a slight development of carbonic acid; whilst it has been proved by the experiments of Davy, Nasse, Scherer, Magnus, and Lehmann (Op. cit., vol. ii. p. 190), that the capacity of defibrinated blood (*i. e.* of serum + corpuscles) for absorbing oxygen and carbonic acid, is much greater than that of serum alone, being at least twice as much for equal volumes. Hence it seems certain, that the Red Corpuscles must contain a large proportion of the gases of the blood (§ 179).—The Red Corpuscles are considerably heavier than the serum in which they are suspended, their normal specific gravity being from 1088·5 to 1088·9 in man, and from 1088·0 to 1088·6 in woman; while that of the Serum averages 1028.

161. In addition to what has been already stated of the influence of

admirable Essay of Schmidt, "Characteristik der Cholera," that Physiologists and Chemists are indebted, for the first direction of their attention to the importance of separately estimating the composition of these two principal constituents of the Blood, and for the indication of the means of doing so

* So long as the error of identifying the substance of Muscle with the Fibrin of the Blood prevailed amongst Chemists and Physiologists, the idea stated above would have had little weight; but now that we know that no special relation between them exists, we are free to attribute the source of the Muscular structure to whatever component of the Blood seems most likely to afford it; and in the absence of any very positive distinction between the composition and properties of Albumen and Globulin, the peculiar relation between the mineral constituents of Muscle and those of the Red Corpuscles, seems to be the surest guide that we can adopt.

influence of reagents much more than others do; and he infers that the latter are the older cells, as having the strongest tendency to disintegration; whilst those which present an unusual resisting power, he infers to be young cells which have not yet acquired the normal characters of the red corpuscles.*

162. The Red Corpuscles, when freely floating in the liquor sanguinis of blood no longer in motion, exhibit a marked tendency to approximate one another; usually coming into contact by their flattened surfaces, so that a number of them thus aggregated present the appearance of a pile of coins; or, if the stratum be too thin to permit them to lie in this manner, partially overlapping one another, or even adhering by their edges, which then frequently become polygonal instead of circular. The corpuscles when thus adherent, resist the influence of forces which tend to detach them, and will even undergo considerable changes of shape, rather than separate from each other, if forced asunder, however, they resume their normal form. After thus remaining adherent for a time, they seem to lose their attractive force; for they are then seen to separate from each other spontaneously. This peculiar tendency to aggregation is doubtless one of the circumstances which influences the coagulation of the blood; it is most strongly manifested in inflammatory blood, and assists in the production of the buffy coat (§ 205); whilst, on the other hand, it seems to be neutralized by the action of most saline substances, since, if these be added to the blood, the corpuscles do not run together.

163. Besides the red corpuscles of the Blood, there are others which possess no colour, and might seem to have a function altogether different, these are known as the *White* or *Colourless* corpuscles. Their existence has long been recognized in the blood of the lower Vertebrata, where, from being much smaller than the red corpuscles, as well as from differing widely in shape, they could readily be distinguished (Fig. 33, *c*). But it is only of late (chiefly through the researches of Gulliver,† Addison,‡ and others), that they have been recognized in the blood of Man and other Mammalia; their size being nearly the same with that of the red corpuscles; and the general appearance of the two (owing to the circular form of the latter, and the absence of a central nucleus,) being less diverse (Fig. 34). It is remarkable that, notwithstanding the great variations in the size of the *red* corpuscles in the different classes of Vertebrata, the dimensions of the *colourless* corpuscles are extremely constant throughout; their diameter being seldom much greater or less than 1-3000th of an inch in the warm-blooded

Fig. 34.

Colourless Blood-corpuscles, or Lymph-corpuscles of the Blood. *a*, *b*, small cells such as are found in the Thoracic duct, seen on their flat side at *a*, and edgewise at *b*, *c*, *c*, the same, with obvious nuclei. *d*, *d*, larger cells, with originally-multiple nuclei *e*, *e*, the same, treated with acetic acid, showing the breaking-up of the nuclei

* Op. cit., vol. ii. pp. 184, 185.

† Notes and Appendix to Translation of "Gerber's General Anatomy."

‡ "Transactions of Provincial Medical Association," 1842 and 1843.

the idea naturally arises, that (to use the words of Mr. Wharton Jones) "there is some reciprocal relation between the colourless corpuscles, and the parts outside the vessels, in the process of nutrition." Of the nature of this relation we have no certain knowledge; but if the Red corpuscles discharge the function which has been suggested for them (§ 160), of preparing the nutrient material for muscle and nerve, it may not be deemed improbable that the Colourless corpuscles should perform a similar office for the other albuminous tissues. A very remarkable spontaneous change of form has been observed by Mr. Wharton Jones to take place in the Colourless corpuscles whilst being examined under the microscope,* and this not only in the blood of Man, but in that of animals of all the Vertebrated classes, as also in that of Invertebrata, whose only corpuscles are of this character (§ 165). From some point of their circumference a protrusion of the cell-wall takes place, the form of which seems quite indefinite; soon afterwards, another protrusion may be seen to arise from another part of the cell, the first being either drawn-in again, or remaining as it was; and thus the configuration of the corpuscles may be seen to undergo several changes before the process finally ceases, and this whilst they are floating in their own serum, and the red corpuscles are lying quite passive in their immediate vicinity These changes of form (which bear a striking resemblance to those of the Proteus-cell) are affirmed by Dr. Davaine† to be visible even whilst the blood is circulating through the vessels, in those colourless corpuscles which are retarded by attraction to their walls.

165. The proportion which the White or Colourless corpuscles bear to the Red, is very small in the blood of Man and the higher Vertebrata; being, in the state of health, according to the estimate of Moleschott (which is confirmed by Kolliker‡) not more than 2·55 to 1000. It may undergo a great increase in disease, however, as will be shown hereafter (§ 191). In the oviparous Vertebrata, the proportion is higher; thus it has been observed by Wagner§ to be as 1 : 16 in the blood of a Frog examined in February, and as 1 : 6 in similar blood examined in August. In one Vertebrated animal, the Amphioxus, the Red corpuscles are wanting altogether, their place in the circulating blood being taken by the Colourless. And in the Invertebrate series generally, the corpuscles of the circulating fluid correspond rather to the *colourless* corpuscles of the Blood of Vertebrata, and to the corpuscles of Lymph and Chyle (which may be regarded as the same bodies in an earlier stage of development), than they do to the *red* corpuscles, which are peculiar to Vertebrata.‖ Thus, in one of its most characteristic features, the Blood of Invertebrata (and of Amphioxus) may be likened rather to the Lymph and Chyle of Vertebrated animals, than to their Blood; and this resemblance is strengthened by the fact, that there is no distinction in the former between the *absorbent* and the *sanguiferous* vessels, which, in the latter contain the nutritious fluid in its earlier and in its later stages of

* "Philosophical Transactions," 1846, pp. 64, 71, 90, &c.

† "Mémoires de la Société de Biologie," tom. ii. pp 103-5.

‡ "Manual of Human Histology" (Sydenham Society's edition), vol. ii. p. 330.

§ "Elements of Physiology," translated by Dr. Willis, p. 246.

‖ See Mr Wharton Jones's Memoirs on 'the Blood Corpuscle considered in its different Phases of Development in the Animal Series,' in the "Philos. Trans.," 1846; also "Princ. of Comp. Phys.," 4th ed. §§ 379–382.

"As described by Vogt, Kolliker, and Cramer, they are large colourless vesicular spherical cells, full of yellowish particles of a substance like fatty matter, many of which particles are quadrangular and flattened, and have been called stearine-plates, though they are not proved to consist of that or any other unmixed fatty substance. Among these particles each cell has a central nucleus, which, however, is at first much obscured by them. The development of these embryo-cells into the complete form of the corpuscles is effected by the gradual clearing-up, as if by division and liquefaction, of the contained particles, the acquirement of blood-colour and of the elliptical form, the flattening of the cell, and the more prominent appearance of the nucleus." The process appears to be essentially the same in the Fish, the Reptile, and the Bird, but it takes place too rapidly in the latter class for its stages to be clearly distinguished; whilst in the tadpole the changes occur so slowly that they can be traced in the blood even while it circulates.—The history of the development of the first red corpuscles in Mammalia is nearly the same; but a binary multiplication of these bodies by subdivision (Fig. 36) has been observed in them by Prof. Kolliker* and others, which has not been noticed elsewhere. In watching the stages of this process, it is seen that the partition of the nucleus takes place completely, before that of the cell itself has commenced. The blood-corpuscles of the Human embryo thus formed, are described by Mr. Paget as "circular, thickly disc-shaped, full-coloured, and, on an average, about 1-2500th of an inch in diameter; their nuclei, which are about 1-5000th of an inch in diameter, are central, circular, very little prominent on the surfaces of the cell, and apparently slightly granular or tuberculated. In a few instances, cells are found with two nuclei; and such cells are usually large and elliptical, with one of the nuclei near each end of the long axis."—When the Liver begins to be formed, this multiplication of blood-cells in the entire mass of the blood ceases, and in a short time all trace of the development of the red out of the original colourless formative cells is lost; whilst, on the other hand, there takes place in the vessels of the liver a new production of colourless nucleated cells, which are formed around free nuclei, and which undergo a gradual change (by the development of colouring matter in their interior) into red nucleated cells resembling those of the first brood. According to Kolliker (Op. cit., p. 343), this new formation of blood-corpuscles in the liver continues to take place during the whole of the fœtal life of Mammalia, as in Birds during incubation (§ 132). Whether these

Fig. 36.

Blood-corpuscles of *Fœtal Lamb*; a, a, bi- and tri-nucleated large colourless elongated blood-cells, in different stages of subdivision; b, b, spherical blood-cells, one of them having a nucleus beginning to divide; c, a smaller cell of the same kind.

* See his Memoir 'Ueber die Blutkörperchen eines menschlichen Embryo, &c.,' in "Zeitschrift für ration. Med.," 1846; and his "Manual of Human Histology" (Sydenham Society's edition), p. 342.

to the influence of water; more liable to corrugation and to collect in clusters; and heavier, so that the smallest and fullest-coloured corpuscles always lie deepest in the field. Thus the most developed state of the Mammalian red corpuscles appears to be that in which they are full-coloured, circular, biconcave, small, uniform, and heavy; this is the state in which they appear to live the longer and most active portion of their lives." On the other hand, Mr. Wharton Jones has adduced very cogent evidence, derived chiefly from a comparison of the sizes of the true red corpuscles of different Mammals, with those of the nuclei of the nucleated corpuscles which their blood contains, that the former are the equivalents of the latter, in a state of higher development, having acquired a vesicular character, and having their interior occupied by globulin and hæmatine. This view certainly harmonizes well with the fact, which can scarcely be explained on the preceding hypothesis, that the red corpuscles of most Mammalia are *smaller* (often very much so) than the nucleated cells in which they originate.*

169. Thus, then, the Chyle and Lymph seem to be continually supplying, not merely the *pabulum* for organization derived from the food, whereby the components of the liquid part of the blood are replenished as fast as they are withdrawn; but also the rudimentary *corpuscles* which are to be progressively metamorphosed into the coloured discs that float in its current. — A remarkable correspondence has been pointed-out by Mr. Wharton Jones (loc. cit.) between the successive phases presented by the Blood-corpuscles in the animal series, and those through which, according to the views above stated, the Red corpuscle passes in attaining its complete form in the highest animal. For in the blood of the Invertebrata, as in the chyle and lymph, and occasionally in the blood, of Vertebrata, are found 'coarse granule-cells,' which seem to be in the first stage of development, and 'fine granule-cells,' which may be regarded as in the second. These lead-on to the 'colourless nucleated cell,' which is the highest form presented by the corpuscles in Invertebrated animals, but is, as we have seen, a mere transitional stage of brief duration in those of Vertebrata. The 'coloured nucleated cell,' again, is the highest form of red corpuscle in the Oviparous Vertebrata; and this corresponds with the first-formed red corpuscle of embryonic Mammalia. The 'red corpuscles' of the fully-formed blood of the latter are to be regarded as exhibiting that highest phase of development, in which the nucleus, having escaped from its parent-cell, itself assumes much of the cellular character. In its early state, this 'cellæ-form nucleus' is uncoloured; but it so soon acquires the red hue, that it is rarely met-with in its earlier state. Fully admitting, however, that, in one mode or the other, the Red corpuscle is originally developed from the lymph-globule, and that this is also the source of the Colourless corpuscle, still it would seem quite possible, that the Red and the Colourless corpuscles are to be regarded as two distinct and complete forms, neither being capable of metamorphosis into the other, and each having a specific purpose to serve

* See "Philosophical Transactions," 1846, pp. 75—79.—Mr. Wharton Jones's views on this point have been adopted by Messrs. Busk and Huxley; see their translation of Prof. Kolliker's "Human Histology" (Sydenham Society's edition), vol. ii. p. 347, note; and "Quart. Journ. of Microsc. Science," vol. i. p. 145.

than an approximative estimate of their respective amounts, and may be best founded on the comparative analyses of the Corpuscle Liquor Sanguinis already cited from Prof. Lehmann (§ 160), it assumed that the *moist* Corpuscles form *half* of the entire volume of blood. This is probably rather beneath than above the actual ave which he considers to be 512 parts in 1000, the limits of variatio health, however, are about 40 parts on either side. By halving

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The second specimen was from a robust man twenty years old.—

	Scherer.	Becquerel and Rodier.	Hoffe.	Gorup-Besanez.
Water	783·63	783·63	783·63	783·63
Solid matters	216·37	216·37	216·37	216·37
Fibrin	1·56	1·56	1·56	1·56
Corpuscles	113·54	131·52	115·12	115·12
Albumen	64·32	65·91	51·76	62·74
Extractive matters and salts	36·95	17·38	47·93	36·95

As the greater number of results hereafter to be cited, have been obtained by method of MM. Prevost and Dumas, which has been followed, with slight modificati by MM. Andral and Gavarret ("Essai d'Hæmatologie Pathologique"), and by Becquerel and Rodier ("Recherches sur la Composition du Sang," &c.), it will be adv tageous here to describe it. The blood which is being drawn for analysis, is received two different vessels, the first and the last quarters of the whole amount into one, and second and third quarters into the other; in this manner, the similarity of the two tities is secured as far as possible. The blood in one vessel (A) is allowed to coag spontaneously; that contained in the other (B) is beaten with a small rod to separate the fibrin. When the coagulation has fully taken place in A, the serum is fully separated from the crassamentum; and there are then dried and weighed, 1. Fibrin obtained by the rod (B); 2. The entire Crassamentum (A); 3. The Serum The weight of the separated fibrin gives the amount of it contained in the clot. weight of the dried residue of the serum gives the proportion of its solid matter to water. The quantity of water driven off from the clot in drying, gives the amount serum it contained, from which may be estimated the quantity of the solids of the seru contained in the crassamentum. Hence by deducting from the weight of the whole clot, first the weight of the fibrin separated by stirring, and then that of the solid matt of the serum as obtained by calculation, we obtain as a residue the weight of the c puscles. In order to ascertain the whole amount of solid matter in the serum, that wh was ascertained by calculation to exist in the coagulum, must be added to that which obtained from the separated serum. Finally, the proportions of organic and of inorgan matter in the solids of the serum are ascertained by incinerating them in a crucible, which the whole of the former will be driven-off, the latter being left.

Both of the foregoing methods, like most others, are open to the objection, that th albuminous and other constituents of the serum are reckoned in the calculation as bein equally present in the *whole* water of the blood. Now as the *moist* Corpuscles, accordi to Schmidt, constitute *fully half* the mass of the blood, and as they do *not* contain th albuminous elements of the serum, and have salines peculiar to themselves, it is obvio that the constituents of the Serum will be estimated far *too high*, and the residue, whic expresses the solid matter of the Corpuscles, as much *too low*. Moreover, this method analysis gives no account whatever of the Salts contained in the Corpuscles, which, as w have seen (§ 160), are very different from those of the Serum; and these can only b determined by the incineration of the whole mass of the blood. For an account of th methods of analysing the blood, employed by Berzelius, Denis, and Simon, see th "Animal Chemistry" of the last-named author (Sydenham Society's Ed., vol. i. pp. 167 et seq.), and for a critical comparison of these and other methods more recently devised see Prof. Lehmann's "Physiological Chemistry" (Cavendish Society's Ed., vol. ii. pp. 218 et seq. The method of Schmidt, which is approved by the last-named authority, is base on very ingenious investigations and calculations, by which he has shown that if the weigh of the *dry* corpuscles, obtained by the method of Prevost and Dumas, be multiplied by 4, it will give the weight of the *moist* corpuscles.

it may thus be made so perceptible as to admit of their blood being distinguished (at least by an individual possessed of a delicate sense of smell) through its scent alone. Of this test, use has been made with great advantage in juridical investigations.*

172. Under the vague term *Extractive*, have been included many different substances which normally present themselves in only very small quantity, and which are consequently very difficult of detection, but which are extremely important in a physiological point of view, as the chief 'factors' (to use the appropriate designation of Prof. Lehmann) in the metamorphosis of animal tissue, both *progressive* and *retrograde*. Some of these, such as the compounds which have been designated by Mulder as the binoxide and tritoxide of protein, appear to be histogenetic substances in the course of preparation for organization; very little, however, is certainly known respecting them. Glutin (gelatin) also has been recently detected in the blood, but this, for the reasons already given (§ 51), can scarcely be regarded as a histogenetic substance, and must have been probably derived directly from the food, and have been waiting to be excreted. Of the products of retrograde metamorphosis, however, which are on their way to the excretory organs, our knowledge is much more precise; and already there have been detected in the extractive the principal components of the biliary and urinary excretions, namely, cholic acid,† urea, creatine and creatinine, and uric and hippuric acids, and also hypoxanthin, and formic, acetic, and lactic acids.‡ Much attention has recently been given to the *red crystals* which form in blood after it has been at rest for some time, and especially if it have been diluted with water. These crystals present a considerable variety of forms in different animals (Fig. 37), and at different stages of decomposition in the blood of the same animals; and they present also very marked diversities in chemical properties, some being readily soluble in water, whilst others are insoluble in water but soluble in acetic acid, and others are insoluble either in water or acetic acid. The reactions of some of these crystals would seem to indicate that they are formed, or at least derived, from protein-compounds; but others seem rather to consist of phosphoric acid, in 'conjugation' with an organic substance. The whole matter is at present involved in great obscurity; but it can scarcely be doubted that, whatever be the nature of this crystalline sub-

FIG. 37.

Blood Crystals, (1) prismatic, from Human blood, (2) tetraedral, from Pig's blood, (3) hexagonal plates, from Squirrel's blood.

* See M. Barruel's researches on this subject in "Ann. d'Hygiène," &c. tom. i. ii. x.

† The presence of cholic acid, in combination with soda, as a normal ingredient in blood, seems lately to have been substantiated by Enderlin. See the account of his researches, 'Cholsaures Natron in Blute,' in Schmidt's Jahrb. i. 1853.

‡ See Lehmann's "Physiologischen Chemie," 2nd edit., band ii. p. 190.

174. We have now to inquire into the principal modifications, which the relative proportions of these constituents undergo in the state of health, under the influence of varying conditions of the system; and notwithstanding the want of *absolute* correctness in the analyses of which we are at present in possession, those that are made by similar methods give results sufficiently trustworthy to enable them to be compared together and thus to give a tolerably correct indication of the circumstances which determine the *increase* or *diminution* in the principal components of the Blood.—The first of these modifying conditions which requires special notice, is *Age*. During the latter part of fœtal life, the blood is remarkably rich in solid contents; it being in the proportion of corpuscles (including iron), that the chief difference exists between fœtal and maternal blood. This appears from the following comparative analyses made by Denis* of the venous blood of the mother, and of the blood of the umbilical artery, which last has been recently found by Poggiale (as might be expected) to be identical with that of the body of the fœtus.

	Venous Blood of Mother.	Blood of Umbilical Artery
Water	781·0	701·5
Solid constituents	219·0	298·5
Fibrin	2·4	2·2
Corpuscles	139·9	222·0
Albumen	50·0	50·0
Phosphorized Fat	9·2	7·5
Peroxide of Iron	0·8	2·0
Extractive	4·2	2·7
Salts	12·5	12·1

The analyses of Poggiale† give 255·8 parts of solid matter, of which 172·2 parts were corpuscles, and 2 parts of peroxide of iron, in 1000 parts of fœtal blood, thus agreeing with those of Denis in the main fact of the excessive proportion of corpuscles and iron.—The proportion of corpuscles seems to remain high for a short time after birth, but it gradually diminishes; and the whole amount of solid matter in the blood seems to fall to its lowest point during the period of childhood. Towards the epoch of puberty, however, the amount of solid matter increases again, the chief augmentation being in the corpuscles; and it remains at a high standard during the most vigorous period of adult life, after which it begins to decline. This is made apparent in the following table, deduced from the analyses of Denis, which are confirmed by those of Lecanu and Simon.‡

						Solid Constituents
In 5	individuals	between	5 months	and 10 years		170
13	,,	,,	10 years	and 20	,,	200
11	,,	,,	20 ,,	30	,,	240
12	,,	,,	30 ,,	40	,,	240
6	,,	,,	40 ,,	50	,,	240
8	,,	,,	50 ,,	60	,,	220
2	,,	,,	60 ,,	70	,,	210

175. An appreciable difference exists between the blood of the two *Sexes;* that of the male being richer in solid contents, and especially in

* "Recherches Expérimentales sur le Sang humain," and "Simon's Animal Chemistry," vol. i. p. 238.

† "Comptes Rendus," tom. xxv. p. 198. ‡ "Animal Chemistry," vol. i. pp. 237-239.

The observations hitherto made upon the first of these points, however, are not sufficiently numerous to admit of being generalized, and the only points that can be definitely stated, are those which have been substantiated by Profrs. Buchanan and R. D. Thompson,* in their examination of blood whose serum exhibits the 'milky' appearance, which, when it occurs in health, is due to the entrance of chyle, more rapidly than its oleaginous matter can be eliminated by the respiration or appropriated by the tissues. When a full meal containing oily matter is taken after a long fast, and a small quantity of blood is drawn previously to the meal and at intervals subsequently, the serum, though quite limpid in the blood first drawn, shows an incipient turbidity about half an hour afterwards, this turbidity increases for about six hours subsequently, after which it usually begins to disappear. The period at which the discoloration is the greatest, however, and the length of time during which it continues, vary according to the kind and quality of the food, and the state of the digestive functions. Neither starch nor sugar, nor protein-compounds, alone or combined, occasion this opacity in the chyle; but it seems essentially dependent upon an admixture of *oleaginous* matter with the food. There are few ordinary meals, however, from which such matter is altogether excluded. When such milky serum is examined with the Microscope, the opacity is found to be due to the presence of an immense number of exceedingly minute granules, resembling in appearance those which form the 'molecular base' of the chyle (§ 135). They seem to be composed of two chemically-distinct substances, for when the milky serum is agitated with ether, a part is dissolved, whilst another portion remains suspended; and this latter is soluble in caustic potass. The former, therefore, appears to be identical with the 'molecular base' of the Chyle, and to be of an oily or fatty nature; whilst the latter belongs to the protein-compounds. The Crassamentum of such blood often exhibits a pellucid fibrinous crust, sometimes interspersed with white dots, and this seems to consist of an imperfectly-assimilated protein-compound, analogous to that found in the serum. The quantity of this varies according to the amount of the protein-compounds present in the food. The increase of *saccharine* matter in the blood (in which it forms part of the 'extractive'), after the ingestion of a large quantity of saccharine or farinaceous aliment, has been noticed by many experimenters, and has lately been made the subject of attentive study by Von Becker.† He has found that the blood of Rabbits fed on carrots, contained 0·584 per cent. of sugar, whilst that of rabbits fed on oats contained only 0·109 per cent. the blood of the same animals after 24 hours' starvation, contained only 0·045 per cent.; whilst as much as 1·198 per cent. was found in the blood of a rabbit, into whose food so large an amount of sugar had been introduced that it passed away with the excrements. The proportion contained, however, in the blood of Oxen, Dogs, and Cats, is far smaller than this; being (according to the researches of Schmidt)‡ from 0·00069 to 0·00074, 0·0015, and 0·0021 per cent. respectively.—It might be fairly presumed that a temporary augmentation must take place in the *aqueous*

* "Medical Gazette," Oct. 10, 1845.

† "Zeitschr. fur wissenschaft. Zool.," 1853, cited in Prof. Lehmann's "Physiologische Chemie," 2nd edit., band ii. p. 217.

‡ "Characteristik der Cholera," §§ 161–164.

contains a considerably smaller amount of solid matter, than that wh first issued. This fact, which has long been known, has of late been mo precisely determined by Drs. Zimmerman,* Polli,† and J. Davy ‡ Wh blood has been repeatedly drawn, or has been lost by hæmorrhage, that wh remains is impoverished, but the reduction in its whole amount of so matter here also lies rather in the diminution of the corpuscles, than that of the other constituents. This is shown by the following table the results of MM. Becquerel and Rodier's analyses of the blood of patients, each of whom had been bled three times.—

	1st Venesection	2nd Venesection	3rd Venesect
Specific gravity of defibrinated blood .	1056·0	1053·0	10[illegible]·6
,, ,, serum	1028·8	1026·3	102[illegible]
Water	791·0	807·7	8[illegible]·1
Solid residue	207·0	192·3	17[illegible]·9
Fibrin	3·5	3·8	3·4
Corpuscles	129·2	116·3	9[illegible]·4
Albumen	65·0	63·7	64·[illegible]
Extractive and saline matters . .	7·7	6·9	8·0
Fat	1·6	1·6	1·5

Hence it is obvious that the special effect of bleeding is to lower the pro portion of Red corpuscles, and that it has no power of effecting a dimin tion in the amount of fibrin. We shall find, indeed, that in inflammato diseases the amount of fibrin undergoes an extraordinary increase (§ 19 which is not checked in the slightest appreciable degree by the mo copious venesection.—It is remarkable that after very considerable los of blood, a decided increase shows itself in the proportion of Colourle corpuscles, not only *relatively* (as to the red) but *absolutely*; so that, in th blood of a Horse from which 50 lbs. have been previously abstracte the coloured and the colourless corpuscles appear to exist in equ numbers.§

179. We have now to consider the differences which present themselve in the composition of the Blood drawn from different vessels of the sam body; these, it is obvious, being dependent on the changes to which th fluid is subjected, during its passage through organs that will appropria or change its several constituents in an unequal degree. And the fir and most important of these sets of differences, is that which exis between *Arterial* and *Venous* blood. The analyses already cited havin been made chiefly upon the latter, it will be sufficient here to state th general results of comparative inquiries into the composition of the forme The quantity of solid constituents pertaining to the *Corpuscles* is smaller they contain relatively more hæmatin and salts, but much less fat. Th liquor sanguinis is somewhat richer in *Fibrin*; but it contains a large proportion of water, and consequently less *Albumen*. The *Fatty matter* of the serum, as well as of the corpuscles, are considerably diminished; on the other hand, the *Extractive matters* are decidedly increased. It is affirmed by Dr. G. O. Rees,|| that the phosphorus which exists in venous blood in an unoxidized state, united with the fat of the corpuscles, is con-

* "Heller's Archiv.," band iv. p. 385.
† See "Medico-Chirurgical Review," Oct. 1847.
‡ "Anatomical and Physiological Researches," vol. ii. p. 28
§ Kölliker's "Manual of Human Histology" (Sydenham Society's Edit.), vol. ii. p. 33
|| "Philosophical Magazine," vol. xxxiii. p. 28

is fully confirmed by the experiments of Dr. Gairdner,* on the influence of the respiration of pure oxygen on the production of fibrin. As the Rabbit was on many accounts the most convenient warm-blooded animal for such a trial, he first set himself to determine the normal proportions of the constituents of its blood. The analysis of the blood drawn from the aorta in six healthy individuals, yielded the following results :—

	Mean	*Max*	*Min.*
Fibrin . .	1·65	2·00	1·45
Corpuscles	82·35	92·00	70·00
Albumen . .	46·30	58·00	37·20

On the other hand, the analysis of the blood of three individuals which had been made to respire pure oxygen for half an hour, gave the following as the proportions of its components :—

	Mean	*Max.*	*Min.*
Fibrin . .	2·40	2·50	2·30
Corpuscles . .	69·56	75·00	60·50
Albumen . . .	40·23	45·70	35·00

It is further stated by Dr. Gairdner (Op. cit., p. 183), that a rabbit having been kept for half an hour under the influence of an electro-magnetic current between the chest and spine, which produced a great acceleration in the respiratory movements, its blood was found to contain as much as 2·9 parts of fibrin in 1000.—The larger quantity of fibrin in arterial blood of itself renders its coagulum firmer; but independently of this, there would seem to be a difference in the quality of the fibrin, which, when separated by stirring or whipping, is more tenacious and compact in arterial than in venous blood.

181. The proportion of Red Corpuscles in arterial and venous blood respectively, has been variously stated by different observers; and we may easily conceive it to be affected by several circumstances, which may produce a change in the whole proportion of the solid to the fluid constituents of the blood, during the course of its circulation. Thus, the discharge of the contents of the thoracic duct into the venous system near the heart, will tend to dilute the blood of the pulmonary and arterial circulation; whilst, conversely, the escape of the watery part of the blood by the renal and cutaneous secretions, and by transudation into the tissues, which takes place during its passage through the systemic capillaries, will tend to augment the proportion of the solids of the blood drawn from the systemic veins. On the other hand, if the discharge of fluid from the thoracic duct be suspended, and the amount absorbed from the tissues during the systemic circulation should exceed that which is transuded (as appears sometimes to happen, § 178), then the proportion of solid matter will be less in venous than in arterial blood. No such explanation will apply, however, to the very marked differences exhibited in Dr. Gairdner's experiments just cited, between the proportions of red corpuscles and of albumen in the ordinary arterial blood of rabbits, and in that of the individuals whose blood had been hyper-arterialized; the sum of the averages in the former case being 128·65, and in the latter 109·79, the difference of which is 18·86, or nearly *one-seventh* of the larger amount. Still, that this difference is in great part due, rather to dilution

* Treatise "On Gout," 2nd edit., pp. 153-4.

carbonic acid, respectively, upon the form of the corpuscles, confirms the idea that this is the mode in which these agents affect their colour; for the former causes their contraction, and renders their cell-walls thick and granular, so as to increase their power of reflecting light; whilst the latter, producing a dilatation of the corpuscles, thins their cell-walls, and enables them to transmit light more readily. That an increase in the opacity and reflecting power of the corpuscles tends to heighten the colour of the blood, is shown by an experiment of Scherer's, who found that when defibrinated blood had been darkened by the addition of water, its original bright colour was restored by the addition of a little milk, or finely-powdered chalk or gypsum.*

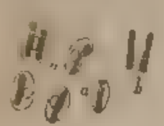
183. Although no difference can be detected between samples of blood drawn from various parts of the *Arterial* system of the same animal, very important variations exist, as might be expected, in the composition of the blood drawn from the several parts of the *Venous* system; since the changes to which it has been subjected in the several organs through which it has passed, are of a very diversified character. The blood of the Vena Portæ, for example, differs considerably from the blood of the Hepatic vein, and both of these differ from the blood of the Jugular. So, again, the blood of the Splenic vein differs from all the preceding; and so must the blood of the Renal vein, although this latter difference has not yet been demonstrated by direct analysis. The most important and best established of these diversities will now be enumerated. In speaking of the composition of the blood of the *Vena Portæ*, it must be remembered that this consists of two very distinct factors, namely, the blood of the Gastric and Mesenteric veins, and the blood of the Splenic vein; the former having been altered by the introduction of solid and liquid alimentary matters, and the latter by its circulation through the spleen. These, therefore, ought to be separately studied; and this has been done by M. Jules Béclard.† The characters of the blood returning by the *Gastric* and *Mesenteric* veins from the walls of the alimentary canal, are of course affected by the stage of the digestive process, and by the nature and amount of the absorbable matters. As compared with the ordinary venous blood, the total quantity of its solid constituents is lowered during the early part of the digestive process, by the dilution it suffers through the imbibition of liquid; and this diminution is especially remarkable in the corpuscles, the relative proportion of albumen being increased by the introduction of new albuminous matter from the food. Towards the conclusion of the digestive process, however, the blood of the mesenteric veins gradually comes to present the ordinary proportions of these two components; and in an animal that has been subjected to long abstinence, it does not differ from that of the venous system in general. The

* See, on this subject, the reports by Scherer in "Canstatt's Jahresbericht" for 1844 and subsequent years, and the works therein referred to; also Muller's "Chemistry of Animal and Vegetable Physiology" (translated by Prof. Johnston), pp. 338–344.—It has been lately found by Bruch, that blood impregnated with oxygen becomes darker under the air pump; while blood saturated with carbonic acid and placed *in vacuo* did not become lighter, but retained its characteristic dark tint (whether treated with water or not), notwithstanding the loss of a large quantity of carbonic acid. (See "Zeitsch. für Wissen. Zool.," band iv. p. 273.)

† See his Memoir in the "Arch. Gén. de Méd.," 4e série, tom. xviii. p. 322, et seq.; and his edition of his father's "Elemens d'Anatomie Generale," pp. 265, 266.

from the interior of the organ itself after its removal, the splenic vein having been previously tied. The nature and amount of these changes, however, differ in a very marked degree, according to the stage of the digestive operation and the general condition of the nutritive function; and it is to this circumstance, that we are probably to ascribe much of the diversity in the results obtained by previous experimenters. A marked decrease in the total amount of solid matter is generally observable; the average of twelve experiments giving only 187·1 per 1000 of solid constituents in the splenic blood, whilst the arterial blood of the same animals contained 239 parts, and the jugular venous blood 2.. parts. This decrease depends upon the diminished proportion of red *corpuscles*, which seems always to present itself, except in starved or extremely ill-fed animals; the amount of this reduction, however, varies extremely, having been, in one of the horses experimented on by Mr Gray (Op. cit., p. 157), somewhat less than one-fourth, in another about one-third, in another about one-half, in another as much as two-thirds, and in another no less than five-sevenths. On the other hand, the *albumen* usually exhibits a marked increase, which may even double its previous amount; and this seems greatest at an interval of some hours after feeding. The *fibrin* seems to be almost constantly augmented, and this sometimes in a very remarkable degree; the quantity found in the splenic blood varying from 2·5 to 11·53 parts in 1000, or from an amount a little above the usual standard, to nearly six times that average. It does not appear, however, that the increase of fibrin and albumen stands in any such relation of uniformity to the diminution of the red corpuscles, that the augmentation of the former may be directly attributed to the disintegration of the latter; so that these changes would rather seem to be concurrent, than to be mutually dependent.* The blood of the Splenic vein is further remarkable for the large proportion of colourless corpuscles (apparently derived from the white portion of its parenchyma) which it includes; and also for containing a number of peculiar cells including rod-like crystals of reddish-yellow colouring matter (Fig. 38), which seem to be red corpuscles in a state of degeneration (§ 142, III).

FIG. 38.



Blood-corpuscles with rod-like yellow crystals, from Splenic Vein of Perch: a, a, blood-cells, treated with water; b, free crystals.

185. Many comparative observations have been made upon the blood of the *Vena Portæ* and of the *Hepatic vein;* but a large part of them, according to M. Cl. Bernard, are vitiated by the fact, that, unless the vena portæ be tied, a reflux of blood takes place into it from the liver, so that the blood which flows when it is wounded, is not so much portal as hepatic blood. According to this experimenter, the blood of the hepatic vein is peculiar as containing an increased proportion not only of sugar but also of fat; these substances being generated, during the

* It seems obvious that such an enormous diminution of the Red Corpuscles can only take place in blood which is partially or completely *stagnated* in the organ; since, if the circulation through it were taking-place at the usual rate, all the blood in the body would be speedily subjected to the process, and its corpuscles would be (as it were) entirely melted down. For a statement of Mr Gray's views, with critical observations thereon, see the "Brit. and For. Med.-Chir. Rev.," Jan., 1855.

blood drawn from the renal artery, and only 778 in blood drawn from the renal vein of the same animal.* the proportion of salts, however, has not been analytically determined to be different.

186. *Alterations in the Composition of the Blood in Disease.*—Under this head it is intended here to consider, not the state of the Blood in every principal type of disease (which it is the duty of the Pathologist to investigate), but the most important facts which the study of its morbid conditions has afforded, towards the determination of the conditions under which decided variations take place in the quantity and quality of its principal components, and of the effects which these variations produce upon the system at large. The first series of such connected researches, as afford the requisite materials for this inquiry, was that of MM. Andral and Gavarret,† which is still of standard value; this was followed by the investigations of MM. Becquerel and Rodier,‡ and many additional analyses have been made by Popp, Simon, and other observers. For the purpose of comparison, however, as already remarked, it is desirable to employ those results only, which have been obtained by processes essentially the same; and hence the following summary will be chiefly based on the statements of the French experimenters whose researches have been just referred-to.—It is necessary, however, in the first place, to assume some standard of composition, which may be regarded as sufficiently characteristic of health, to lead us to regard any variation which passes beyond its limits as essentially morbid; and this standard must be fixed according to the method of analysis employed. Thus, although it has been shown (§ 170, *note*) that the calculation of the proportionals of the principal constituents of the blood, from the results obtained according to the method of MM. Andral and Gavarret, must be held to be in itself erroneous, yet as the same method was followed in all the analyses of morbid blood made by them and their successors, the requisite standard must be erected upon this foundation; and the following may thus be considered as the normal range of variation for the principal constituents of the blood in health, according to the foregoing mode of estimating them:—

Fibrin	from	2	to	3½	parts per 1000.
Red Corpuscles .	,,	110	,,	152	,, ,,
Solids of Serum .	,,	72	,,	88	,, ,,
Water	,,	760	,,	815	,, ,,

187. The first of these components whose variations we shall consider, is *Fibrin*, the estimate of which, however, is open to an important fallacy, that has not been sufficiently guarded-against,—namely, the admixture of the Colourless corpuscles. "These," as Mr. Paget correctly remarks, "cannot, by any mode of analysis yet invented, be separated from the fibrin of mammalian blood; their composition is unknown, but their weight is always included in the estimate of the fibrin. In health, they may, perhaps, add too little to its weight to merit consideration, but in many diseases, especially in inflammatory and other blood diseases in which the fibrin is said to be increased, these corpuscles become so numerous that a large proportion of the supposed increase of the fibrin

* "Simon's Animal Chemistry" (Sydenham Society's Ed.), vol. i. p. 214.

† "Essai d'Hæmatologie Pathologique."

‡ "Recherches sur la Composition du Sang dans l'Etat de Santé et dans l'Etat de Maladie."

When the disease presents alternations of increase and decline, these are marked by precisely-corresponding changes in the quantity of Fibrin. An augmentation is commonly observable during the advanced stage of Phthisis, in spite of the deterioration which the blood must then have undergone; this is probably dependent upon the development of low inflammation around the tubercular deposits. In one of Popp's observations, the proportion of fibrin in the blood of a phthisical patient was not less than 10·7.—Some experiments performed by M. Andral on the blood of pregnant women, seem to lead to the conclusion that, during the first six months, the Fibrin is below the normal standard, and that it subsequently varies, usually undergoing an augmentation between the sixth and seventh, and the eighth and ninth months. There is also a diminution in the Corpuscles, and these circumstances combined favour the production of the 'buffy coat' (§ 206). These observations are confirmed by those of MM. Becquerel and Rodier.

189. It appears obvious, from what has been just stated, that the increase in the quantity of Fibrin is not *dependent upon* the febrile condition which is secondary to the local inflammation, but upon the Inflammation itself. This conclusion is confirmed by the interesting fact that, in idiopathic Fever, the proportion of Fibrin is diminished instead of undergoing an increase. This diminution was constantly observed by Andral in the premonitory stage of Continued Fever; in some instances the amount was no more than 1·6 parts in 1000. The proportion of Corpuscles was found to have usually, but not constantly, undergone an increase; as had also that of the solid parts of the Serum. In ordinary Continued Fever, in which there was no evident complication from local disease, the quantity of Fibrin varied from 4·2 to 2·3; that of the Corpuscles from 185·1 to 103·6 (excluding a case in which their amount was only 82·5, which was that of a Chlorotic female); that of the solid matter of the Serum, from 98·7 to 90·9; and that of the Water from 725·6 to 851·9. Hence the quantity of solid matter appears to be usually increased; but the peculiar condition of the blood in this disease may probably be stated to be (so far as regards the proportions of its principal constituents) a diminution of the Fibrin in proportion to the Red Corpuscles. When, however, a local Inflammatory affection developes itself during the course of the Fever, the amount of Fibrin increases; but its augmentation seems to be kept down by the febrile condition.—In Typhoid Fever,* the decrease in the proportion of Fibrin is much more decidedly marked; this does not depend upon abstinence; for it ceases as soon as a favourable change occurs in the disease, long before the effect of food could show itself. In the various cases examined by Andral, the blood furnished a maximum of 3·7 of fibrin, and a minimum of 0·9; in this last case, the typhoid condition existed in extreme intensity, yet the patient recovered. The proportion of Corpuscles varies considerably; in an early stage of the disease it is usually found to be absolutely high; and it always remains high, relatively to the amount of fibrin. In Typhoid Fever, then, the abnormal condition of the Blood, in regard to the disproportion between the corpuscles and the fibrin, is more strongly marked than in ordinary continued fever; yet

* M. Andral confines this term to the species characterised by ulceration of the mucous follicles of the intestinal canal.

which the blood was analysed by Routier,* the proportion of corpuscles was normal (nearly 122 parts in 1000), whilst the fibrin only amounted to 0.9 parts in 1000.

190. The amount of *Red Corpuscles* seems to be subject to greater variation within the limits of ordinary health, than is that of fibrin. In the condition which is ordinarily termed a highly sanguineous temperament, or Plethora, it is chiefly the entire mass of the blood that undergoes an increase; but whatever excess there may be in the proportion of its solid constituents, this affects the Corpuscles rather than the fibrin. Plethoric persons are not more prone to Inflammation, than are those of weaker constitution; but they are liable to Congestion, especially of the brain, and to apoplexy or other hæmorrhage. The effect of bleeding in diminishing this tendency is now intelligible; since we know that loss of blood reduces the proportion of corpuscles.—On the other hand, in that temperament,† which when exaggerated, becomes Anæmia, there is a marked diminution of the Corpuscles; this temperament may lead to two different conditions of the system. In Chlorosis, the Red corpuscles are diminished, whilst the Fibrin remains the same; so that the clot, though small, is firm, and not unfrequently exhibits the buffy coat; in some extreme cases of this disease, the Corpuscles have been found as low as 27. The influence of the remedial administration of Iron, in increasing the quantity of Corpuscles, was rendered extremely perceptible by Andral's analyses; in one instance, after iron had been taken for a short time, the proportion of Corpuscles was found to have risen from 49.7 to 64.3; whilst in another, in which it had been longer continued, it had risen from 46.6 to 95.7. On the other hand, Bleeding reduced still lower the proportion of Corpuscles; thus in one instance their amount was found, on a second bleeding, to have sunk from [illegible] to 49. The full proportion of fibrin in the blood of Chlorotic patients seems to account for the infrequency of Hæmorrhage in them; whilst it also leads us to perceive that they may be, equally with others, the subjects of acute Inflammation, which we know to be the fact. But a diminution of Corpuscles may coexist with a diminution in the amount, or in the degree of elaboration, of the fibrin; and this condition seems to be characteristic of Scrofula. Andral has noticed a diminution in the proportion of Red Corpuscles in other Cachectic states, resulting from the influence of various depressing causes on the nutritive powers; as in a case of Diabetes Mellitus, in which the patient was much exhausted; in a case of Aneurismal dilatation of the Heart inducing Dropsy; and in several cases of Cachexia Saturnina. The proportion of Red Corpuscles seems constantly to undergo a marked diminution in Scurvy; and has been found, in some cases of this disease, as low as in intense Anæmia. The same may be said of the advanced stage of Bright's disease of the Kidney, and of 'Leucocythæmia.' A very rapid disintegration of the Red Corpuscles appears sometimes to take place, when a morbid poison is present in the blood, or when its composition has been seriously affected by the loss of its other constituents. Thus Dr. C. J. B. Williams‡

* "Gazette des Hôpitaux," tom. vi. No. 90.

† The term *lymphatic* has been applied to this temperament; by which term was meant a predominance of lymph in the absorbent vessels.

‡ "Principles of Medicine," 2nd edit. p. 115.

the amount of albumen in the serum is reduced below the normal standard. Thus Dr. Christison found the entire solids of the serum to be reduced in some instances to 55 or even 52 parts in 1000, his estimate of their normal amount being 83·4; and he found the specific gravity of the serum to fall as low as 1020 or even 1019, the normal standard being from 1027 to 1031. According to Andral, the diminution in the amount of Albumen in the Serum is exactly proportional to the quantity contained in the Urine *—The proportion of *fatty* matter in the serum, and especially of the cholesterin, has been found by MM. Becquerel and Rodier to undergo an increase at the commencement of most acute diseases; and they have also observed an increase of fat, and especially of cholesterin, in chronic diseases of the liver, in Bright's disease of the kidney, and in tuberculosis. The quantity of fat in the blood sometimes undergoes such an augmentation, as to give to the serum a considerable 'milkiness.' This has been observed by Marcet in a case of diabetes, by Traill in hepatitis, by Christison in dropsy, icterus, and nephritis, by Zanarelli in pneumonia, and by Sion in mammary abscess. In Dr. Traill's case, the whole amount of solid matter in the serum was 202 parts in 1000, as much as 157 parts being albumen, whilst 45 were fat. In Zanarelli's case, the blood contained so small a proportion of red corpuscles, that it seemed milky when it first flowed; and it did not undergo a regular coagulation, but merely separated into a thicker and thinner portion. This blood only contained 95 parts of solid constituents in 1000; and 10 parts of these consisted of fatty matter, and 9 parts of extractive and salines; so that the whole amount of fibrin, corpuscles, and albumen was only 76 parts. In Dr. Sion's case, also, the blood itself was quite milky, it underwent no coagulation; and only a very small quantity of colouring matter was deposited, when it was allowed to stand. This blood was found by Lecanu to contain 206 parts of solid constituents in 1000, but of these no less than 117 parts were fat, the remainder consisting of albumen (64 parts), and of extractive and saline (25 parts). No fibrin could be found, and the quantity of hæmatosine

* A case is related by Andral, under this head, which affords an interesting exemplification of the general facts that have been attained by his investigations. A woman who had been suffering from Erysipelas of the face, and had lost blood both by venesection and leeches, became the subject of Albuminuria. The blood drawn at this time exhibited a considerable diminution in the proportion of Corpuscles, as well as of Albumen, a fact which the previous loss of blood fully accounted for. After a short period, during which she had been allowed a fuller diet, another experimental bleeding exhibited an increase in the proportion of Corpuscles. Some time afterwards, when the Albumen had disappeared from the Urine, some more blood was drawn; and it was then observed that the Albumen of the Serum had returned to its due proportion, but that the Corpuscles had again diminished, whilst there was a marked increase in the quantity of Fibrin. This alteration was fully accounted for by the fact, that, in the interval, several Lymphatic ganglia of the neck had been inflamed and had suppurated, and that the patient had been again placed on very low diet. "Thus," observes Andral, "we were enabled to give a complete explanation of the remarkable oscillations which were presented, in the proportion of the different elements of the blood drawn at three different times from the same individual; and thus it is that, the more extended are our enquiries, the more easy does it become to refer to general principles the causes of all those changes in the composition of the blood, which, from the frequency and rapidity with which they occur, seem at first sight to baffle all rules, and to take place, as it were, at random. In the midst of this apparent disorder, there is but the fulfilment of *laws*; and in order to obtain these, it is only necessary to strip the phenomena of their complications, and reduce them to their simplest form."

blood is augmented to but a small degree, a feeling of discomfort and oppression, increasing with the duration of the interruption, is speedily produced. The results of the retention of the materials of the Biliary and Urinary excretions will be hereafter considered (CHAP. IX.); and at present it will be only remarked, that such retention is a most fertile source of slight disorders of the system, that it is largely concerned in producing many severe diseases, and that, if complete, it will most certainly and rapidly bring-about a fatal result.—The most remarkable cases of depravation of the Blood, by the introduction of matters from without, are those in which these substances act as *ferments*, exciting such Chemical changes in the constitution of the fluid, that its whole character is speedily changed, and its vital properties are altogether destroyed. Of such an occurrence, we have characteristic examples in the severe forms of Typhoid fever, commonly termed *malignant*, in Plague, Glanders, Pustule Maligne, and several other diseases; in some of which we can trace the direct introduction of the poison into the blood, whilst in others we must infer (from the similarity of results) that it has been introduced through some obscure channel, probably the lungs. The evidence which we possess of the 'intoxication' of the Blood in these and other cases, derived from the perversion of the nutritive operations which it induces, will be considered in the next Section.

3. *Of the Vital Properties of the Blood, and its Relations to the Living Organism.*

195. It cannot be doubted that the perfect and regular performance of the various actions to which the Blood is subservient, is dependent upon the admixture of its principal components in their due proportions, and upon its freedom from deleterious matters, whether formed within the system, or introduced into the circulating current from without. And it is not difficult to see how any considerable alteration which affects its *physical* conditions merely, may thereby produce a most serious disturbance in the regularity of the circulation, and in the functions to which it ministers. Thus it has been shown by the experiments of Poiseuille,* that a certain degree of viscidity is favourable to the motion of liquids through capillary tubes; a thin solution of sugar or gum being found to traverse them more readily than pure water will do. Hence any serious alteration in the proportion of the organic and saline compounds dissolved in the liquor sanguinis, and especially in that of the Fibrin (on which the viscidity of the blood appears chiefly to depend), might be expected to produce obstruction in the capillary circulation, and to favour transudation of the fluid portion of the blood; and the numerous experiments of Magendie (Op. cit.) seem to favour this view, although they are far from manifesting that character for accuracy and discrimination which would be required to afford an authoritative sanction to it. A much more determinate influence, however, must be exerted upon the Red Corpuscles, by any cause which seriously affects the specific gravity of the liquor sanguinis (§ 158); and the perfect elaboration of the Albuminous constituent of the serum has been shown to be requisite, to prevent it from copiously transuding the membranous walls of the vessels

* See M. Magendie's "Leçons sur les Phénomenes Physique de la Vie," tom. iv. p. 57

Serum. This separation will not occur, however, if the coagulation take place in a shallow vessel; nor if the amount of Fibrin should be small, or its vitality low. A homogeneous mass, deficient in firmness, presents itself under such circumstances; though the solid part of this may pass into a state of more complete condensation after the lapse of a certain time.—That the coagulation is due to the Fibrin, and that the Corpuscles do not take any active share in the process, appears from several considerations.* A microscopical examination of the Clot shows that it has the same texture with Fibrin when coagulating by itself; the Corpuscles clustering together in the interspaces of the network, and not being uniformly diffused through the whole mass. Their specific gravity being greater than that of the Fibrin, they are usually most abundant at the lower part of the clot; and the upper surface is sometimes nearly colourless, especially when the coagulation has taken place slowly; whilst this upper part is much firmer than the lower, showing that the Fibrin alone is the consolidating agent. If, after the complete subsidence of the Corpuscles, a little of the colourless Liquor Sanguinis be skimmed-off, it will undergo complete coagulation, forming a colourless clot; as was long ago shown by Hewson. The same fact may be experimentally demonstrated by the use of methods which effect an artificial separation of the Fibrin from the Corpuscles. Thus Müller placed the blood of a Frog, diluted with water (or still better, with a very thin syrup), on a paper filter of sufficiently fine texture to keep-back the Corpuscles; and the Liquor Sanguinis, having passed through the filter completely unmixed with them, presented a distinct coagulum, although, from the diluted state of the fluid, this did not possess much consistency. Owing to the more minute size of the Blood-discs of warm-blooded animals, this experiment cannot be so readily performed with their blood. So, again, if fresh-drawn blood be continually stirred with a stick, the Fibrin will adhere to it in strings during its coagulation; and the Red corpuscles will be left suspended in the serum, without the slightest tendency to coagulate. Moreover, if a solution of any salt, that has the property of retarding the coagulation (such as carbonate of potash or sulphate of soda), be added to the blood, the Corpuscles will have time to sink to the lower stratum of the fluid, before the clot is formed; the greater part of the crassamentum is then entirely colourless, and is found by the microscope to contain few or no red particles. It will be presently shown, however, that the difference of specific gravity is by no means the only cause of the separation of the Corpuscles from the Liquor Sanguinis (§ 205).

198. That the Coagulation of the Blood is not, as some have supposed, a proof of its death, but is rather an act of vitality, appears evident from the incipient organization which may be detected even in an ordinary clot; and still more from the fact, that, if the effusion of Fibrin take place upon a living surface, its conversion into a fibrous solid is the first act in the production of solid tissues, which become constituents of the

* It is remarkable that this doctrine, clearly established by the older Physiologists, and especially by Hewson, should ever have been put aside, even temporarily, for the untenable hypothesis that the coagulation of the Blood is due to a running-together of the red corpuscles. For an admirable summary of the history of opinion on this subject, see Mr. Gulliver's Introduction to his Edition of Hewson's works (published by the Sydenham Society).

a certain degree of organization with great rapidity, but do not go-on to the same perfection, and speedily degenerate.*

199. Instances occasionally present themselves, in which the Blood does not coagulate after death, or coagulates very imperfectly. It was affirmed by Hunter† that no coagulation occurs in the blood of animals hunted to death, or of those killed by lightning, by electric shocks, or by blows upon the epigastrium; and this statement has been generally received upon his authority. It is far, however, from being constantly true; for Mr. Gulliver has collected numerous cases in which coagulation was found to have taken place in the blood of animals killed in each of these modes; in some of them, however, the coagulation was very imperfect.‡ It is not improbable that some of the instances of apparent *absence* of coagulation, were really cases of *retarded* coagulation (§ 200), and Dr. Polli goes so far as to maintain, that the complete absence of coagulating power is a phenomenon which has no real existence. He states that he has never met with an instance, in which the blood, when left to itself, and duly protected from external destructive influences, did not coagulate before becoming putrid; and that he has more than once found blood to coagulate, which had been taken in a fluid state from the vessels thirty-six or forty-eight hours after death.§ Still there seems no reasonable doubt that non-coagulation *may* occur, when the blood has been previously subjected to conditions which affect the vitality of its fibrin. Such appears to be the case, for example, when death occurs from Asphyxia, as by hanging, drowning, or breathing of irrespirable gases,‖ and the same has been observed in cases of poisoning by hydrocyanic acid, in which asphyxia was probably the immediate cause of death. In certain diseased states, again, we have seen that the coagulating power seems to be completely deficient (§ 189).

200. The length of time which elapses before Coagulation, and the degree in which the clot solidifies, vary considerably; in general, they are in the inverse proportion to each other. Thus, if a large quantity of blood be withdrawn from the vessels of an animal at the same time, or within short intervals, the portions that last flow coagulate much more rapidly, but much less firmly, than those first obtained. In blood drawn during Inflammatory states, again, the coagulation is usually slow, but the clot is preternaturally firm; especially at its upper part, where the Buffy coat (§ 205) or colourless stratum of fibrin, gradually contracts, and produces the 'cup,' which may be generally considered to indicate a high degree of Inflammation. Although the Blood withdrawn from the body coagulates (except under the peculiar circumstances just stated), whether it be kept at rest or in motion, whether its temperature be high or low, and whether it be excluded from the air, or be admitted to free contact with the atmosphere, yet its coagulation may be accelerated or

* See especially Mr. Dalrymple's Memoirs "On the rapid organization of Lymph in Cachexia," in the "Med. Chir. Trans.," vol. xxiii.; and "On the early organization of Coagula and mixed fibrinous effusions under certain conditions of the system," Op. cit. vol. xxvii.

† "The Works of John Hunter," edited by James F. Palmer, vol. iii. pp. 34, 114.

‡ See "Edinb. Med. and Surg. Journ." Oct. 1848, pp. 367, 418, and his Edition of "Hewson's Works," pp. 20, 21.

§ "Annali Universali," 1845, and "Ranking's Abstract," vol. ii. p. 337.

‖ See Dr. J. Davy's "Physiological and Anatomical Researches," vol. ii. p. 192

then take place, although in most cases less perfectly than it would have done at first. There appears to be no limit to the time during which the coagulation may be thus postponed; thus Mr. Gulliver* mentions that he has kept horse's blood fluid with nitre for fifty-seven weeks, and that it still readily coagulated when diluted with water (Op. cit. p. 12). It is not so difficult, therefore, as it might otherwise seem, to give credit to the statement of Dr. Polli, that, in a case witnessed by himself, complete coagulation of the blood did not take place until fifteen days after it had been withdrawn from the body; and that fifteen days more elapsed before putrefaction commenced in it. The upper four-fifths of the clot were colourless, the red corpuscles occupying only the lowest fifth. It is additionally remarkable, that the patient (who was suffering under acute pneumonia), being bled very frequently during the succeeding week, the blood gradually lost its indisposition to coagulate.†

201. It has been maintained by some observers, that a certain amount of heat is liberated during Coagulation; but this idea would seem to have been founded on a fancied analogy between coagulation and freezing; and it is negatived by the careful observations of Hunter, Schroeder Van der Kolk, J. Davy, and Denis.—Again, it has been asserted that the act of coagulation is attended by the extrication of a small quantity of carbonic acid; but there is no sufficient proof that blood in coagulating gives out more carbonic acid, than it ordinarily does by exposure to the air (§ 179). Moreover, it has been shown by the experiments of Sir H. Davy ‡ and Dr. J. Davy,§ that no effect is produced, either in accelerating or retarding coagulation, by placing blood in an atmosphere of nitrogen, nitrous gas, nitrous oxide, or carbonic acid; and it has been found that coagulation still takes place, even if the blood be agitated with carbonic acid.

202. The vital condition of the walls of the blood-vessels appears to have an important influence upon the fluidity of the Blood. Thus it has been found by Sir A. Cooper and Mr. Thackrah, that whilst blood inclosed in a *living* vein retained its fluidity for some time (§ 200), blood similarly enclosed in a *dead* vein, the atmosphere being completely excluded, coagulated in a quarter of an hour. Moreover, inflammation of the walls of the blood vessels (which is a condition of *depressed* vitality, CHAP. VIII. Sect. 3) promotes the coagulation of the blood which they contain; and thus it is, that the trunks both of arteries and veins frequently become choked-up by coagula.‖ Moreover, although there can be no doubt that

* Mr. Gulliver considers this fact, together with the occurrence of coagulation on the thawing of blood which has been frozen whilst yet fluid, as conclusive against the vital character of the act; remarking that if we believe the coagulation to be an effect of life, we must admit that we can freeze and pickle the life (Op. cit. p. 21). No such admission, however, is necessary. We do not freeze and pickle the life; but we simply preserve the vital properties of the substance, by preventing it from undergoing spontaneous change; thus doing the same for the blood, as may be done for seeds, eggs, and even highly organized bodies, which may be kept in a state of 'dormant vitality' for indefinite periods, by cooling or drying them, or by secluding them from the atmosphere. (See "Princ. of Gen. Physiol.")

† "Gazetta Medica di Milano," Genn. 20, 1844; cited in Mr. Paget's 'Report' in "Brit. and For. Med. Rev.," vol. xix. p. 252.

‡ "Researches on Nitrous Oxide," pp. 380-1.

§ "Anatomical and Physiological Researches," vol. ii. p. 71.

‖ It was observed by Hunter, and has been frequently noticed since, that when ampu-

occasioning coagula to form, whilst it is yet actively moving in the vessels of the living body. Thus M. Dupuy found that the injection of cerebral substance into the veins of an animal, occasioned its death almost as instantaneously as if prussic acid had been administered, the circulation being rapidly brought to a stand, by the formation of voluminous clots in the heart and large vessels. These experiments were repeated and confirmed by M. de Blainville.* —The same effect is produced with still more potency, when the substance injected is rather undergoing degradation, than actually dead, for it then seems to act somewhat after the manner of a ferment, producing a marked diminution in the vitality of the solids and fluids with which it may be brought in contact. Such is pre-eminently the case with *pus*, as was long ago observed by Hunter, and as Mr. H. Lee has since determined more precisely. It was found by the latter, that healthy blood received into a cup containing some offensive pus, coagulated in *two* minutes, whilst another sample of the same blood, received into a clean vessel of similar size and shape, required *fifteen* minutes for its complete coagulation. When he injected putrid pus into the jugular vein of a living ass, coagulation took place so instantaneously as to produce an immediate obstruction to the current of blood, so that the vessel at once acquired a cord-like character; and in this mode, the pus was usually prevented from finding its way into the general current of the circulation. Whilst it thus remains circumscribed by a coagulum of blood, the pus so introduced seems to produce no other constitutional disturbance, than is attributable to the local injury; but if the circumscription should be incomplete, and the pus should be carried into the general circulation, it becomes a source of extensive mischief, determining the formation of abscesses in various parts, and producing a most depressing influence on the system at large.† —The effect of certain animal poisons of a still more potent nature, when introduced into the current of the circulation (as by the bite of venomous serpents), appears to be, like that of a high temperature, the entire *destruction* of the coagulating power of the blood, as well as of the vital endowments of the tissues generally (§ 194).

204. The proportions of Serum and Clot which present themselves after coagulation, are liable to great variation, independently of the amount of the several ingredients characteristic of each; for the crassamentum may include, not only the fibrin and red corpuscles, but also a large proportion of the serum, entangled (as it were) in its substance. This is particularly the case when the coagulation is rapid; and the clot then expels little or none of it by subsequent contraction. On the other hand, if the coagulation be slow, the particles of fibrin usually seem to become more completely aggregated, the coagulum is denser at first, and its density is greatly increased by subsequent contraction. When a firm fresh clot is removed from the fluid in which it is immersed, its contraction is found to go-on increasing for 24 or even 48 hours, serum being squeezed-out in

* "Gazette Medicale," 1834, p. 521 —There is no reason to suppose that cerebral substance possesses a more special influence, than would be exerted by any other tissue which could be as easily mixed-up with the circulating current. The presence of a piece of flesh or of the clot of blood, as Prof. Buchanan has shown, often suffices to determine the coagulation of fibrin in a solution from which it would not otherwise have separated.

† See Mr. H. Lee's excellent Treatise "On the Origin of Inflammation of the Veins, and on Purulent Deposits."

rate of sinking increases with their aggregation; so that whilst they sink about an eighth of an inch during the first two or three minutes, they sink through five or six times that space in the next interval of the same length. That the quickness with which they thus aggregate in the lower part of the clot, does not depend (in the case of inflammatory blood) upon the mere facility with which they sink, was further determined by the use of means which tended to diminish or increase their aggregation; thus it was found that the addition of weak saline solutions, by which the liquor sanguinis is attenuated, but which diminish the mutual attraction of the red corpuscles, partially or completely prevented the formation of the buffy coat, in blood which exhibited it strongly when left pure, even though its coagulation was considerably retarded thereby; on the other hand, the addition of mucilage with a small quantity of saline matter, the effect of which is to promote the aggregation of the corpuscles, tended to develope the buffy coat by increasing the rate at which they sink. Now as it has been found that liquor sanguinis deprived of its corpuscles coagulates more slowly than unaltered blood, it does not seem improbable, as Mr. Gulliver has remarked, that this separation of the two components of the crassamentum, which determines the formation of the buffy coat, is partly the cause, rather than the consequence, of the slowness of the coagulation of inflammatory blood.—It is in the buffy coat of inflammatory blood, that we see the clearest indications of organization ever presented by the circulating fluid. The fibrous network is frequently extremely distinct; and it commonly includes a large number of colourless corpuscles in its meshes, these, indeed, being sometimes so numerous, that it is almost entirely composed of them. In its Chemical Composition, the buffy coat of inflammatory blood appears to be peculiar; containing a larger or smaller amount of the substance, readily soluble in boiling water, which is considered by Mulder to be the tritoxide of protein.

Fig. 39.

Microscopic appearance of a drop of *Inflammatory Blood*; the *red* corpuscles lose their circular form, and adhere together; the *white* corpuscles remain apart, and are often more abundant than usual.

206. When the 'buff' arises from other causes, however, its appearance is less characteristic. It appears from the researches of Andral, that the usual condition of its production is an increase in the quantity of Fibrin *relatively* to the red corpuscles, and not a simple augmentation of fibrin. This increase may occur in two ways;—either by an absolute increase in the fibrin, the amount of the corpuscles remaining unchanged, or not being augmented in the same proportion;—or by a diminution of the corpuscles, the quantity of fibrin remaining the same, or not diminishing in the same proportion. Hence in severe Chlorosis, in which the latter condition is strongly developed (§ 180), the 'buffy coat' may be as

the vital endowments of the living tissues with which it is in contact. For, as we have seen, the main condition of coagulation is the diminution or cessation of their agency, either by the withdrawal of blood from the body, or by the death of the organism enclosing it, or by the lowered vitality of the tissues through which it moves (§ 202); whilst mere aëration exerts but a secondary influence upon it (§ 200). And thus we seem entitled to say, that the liquid condition of the fibrin is a result of a balance of forces between the fibrin and the living tissues, those of the former tending to its solidification, whilst those of the latter maintain its fluidity; but that if the latter should be deficient, the former come into uncontrolled action, and expend themselves in the production of a new organized tissue, the higher vitalization of which depends upon subsequent operations (§ 198). The source of this vital endowment of the Fibrinous constituent of the blood, must be looked for in the operations to which the crude albuminous pabulum is subjected, after its first reception into the system.

208. Of the particular purposes which are served by the Fibrin of the blood in the vital economy of the system at large, it must be confessed that we have but little positive knowledge. The idea has been entertained by many Physiologists (including the Author of this treatise), that the fibrin is that element of the blood which is immediately drawn upon in the operations of nutrition; being the intermediate stage between the crude albumen and the solid tissues. This opinion rested in part upon the current doctrine, that fibrin is the constituent of Muscle, and in part upon the assumption, that, as fibrin is more endowed with vital properties than any other of the liquid components of the blood, so as to be capable of passing by itself into the condition of an organized tissue, it must be the one most readily appropriated by the various parts of the solid fabric, as the material for their growth and development. Various considerations have of late been adduced, however, which tend to shake this belief. It has been shown by Liebig,* that so far from there being any evidence of the identity of the Fibrin of blood and the substance of Muscle, the evidence is precisely the other way. On the other hand, there are both structural and chemical indications, that Fibrin is in a state of transition rather towards the Fibro-gelatinous textures, than towards those of the cellulo-albuminous type; for the fibrous network which is formed by its coagulation, bears a greater resemblance to the white fibrous tissue, than to any other texture of the body; whilst the points in which the chemical properties of fibrin differ from those of albumen, are such as manifest a relationship to gelatin. (See PRINC. OF GEN. PHYS.) We seem justified in regarding it, then, as the special pabulum of those *connective* tissues, whose physical offices in the economy are so important, whilst their vital endowments are so low; and as serving, by its own formative power, for the generation of these tissues, wherever and whenever there may be a demand for them.—On the other hand, there is a complete absence of evidence, that the Fibrin of the blood serves any special purpose in the nutrition of the Cellulo-albuminous tissues; and there are various negative indications, that their generation and development do not depend upon its presence. For, in the first place, there is evidence that a fluid destitute of coagulating power may serve the general purposes of nutrition; this being furnished, not merely by such cases as

* "Ann. der Chem. und Pharm." band lxxii.

putting aside its presumed importance in maintaining that physical condition of the blood which is most favourable to its free movement through the vessels, and to its due retention within their walls (§ 195), we find that it is entirely on the coagulating powers of the blood, that the cessation of hæmorrhage from even the most trifling injuries is dependent; that the limitation of purulent effusions by the consolidation of the surrounding tissue, and the safe separation of gangrenous parts, can only take place in virtue of the same property; and that the adhesion of incised wounds, still more the filling-up of breaches of substance, require as their first condition, that either the blood, or matter exuded from it, should be able to assume the state of fibrous tissue.—The results of *deficiency* of coagulating power in the blood, are fearfully seen in the continued and uncontrollable flow which takes place in Purpura, the blood not being able to form a clot sufficient to fill up even the wound made by the scratch of a pin; in the want of circumscription of collections of pus within abscesses, allowing its infiltration through tissues that were previously healthy, and thus occasioning a wide-spread destruction of organized texture, which is characteristic of certain forms of inflammation (this result being usually attributable either to a previously-unhealthy condition of the system, or to the introduction of some specific poison into the blood); in the absence of a corresponding limitation between the living and the dead parts in gangrene, so that hæmorrhage takes place on the separation of the slough, the vessels not having been previously obstructed by coagula; and in the entire failure of any effort, either by simple adhesion, or by the formation of connective tissue, for keeping-together the sides of open wounds, or for bringing the severed parts again into connection (See CHAP. VIII., Sect. 2).—On the other hand, we see the consequences of *excess* of the proportion of fibrin, and of that increased plasticity (or tendency to fibrillate) which usually accompanies its augmentation, in the tendency to form those plastic effusions which are characteristic of the Inflammatory state, and which, if poured-out upon serous or mucous surfaces, constitute 'false membranes' and 'adhesions,' or, if infiltrated into the substance of living tissues, occasion their consolidation. This increased plasticity of the blood, however, may frequently be regarded in the light of an 'effort of Nature' to antagonize the evil consequences of that depression or positive destruction of the vitality of the solid tissues, which seems to form an essential part of the inflammatory condition; and thus it is, that whilst the central part of a mass of tissue, in which the inflammation has been most intense, suffers complete death, and is carried-away in the suppurative process, the peripheral part, in which the violence of the inflammation has been less, becomes infiltrated with plastic matter poured-out from the blood, and forms the solid and impermeable wall of the abscess (See CHAP VIII. Sect. 3.)

210. Turning now to the Corpuscles of the Blood, we have to inquire into *their* special functions, and into the nature of their participation in the vital operations of the system at large. Here, also, we are obliged to rely upon evidence of a far less satisfactory nature than could be desired; and at whatever conclusions we may arrive, we must hold them as probable only, and as liable to be modified by further inquiry. In the first place, upon looking to the chemical constitution of the Red cor-

powers are correspondingly depressed; the capacity for *sustained* exertion, either of the mental faculties, or of the motor apparatus, being almost destroyed, although both the nervous and muscular systems are very easily excited to feeble action.—However difficult it may seem to explain, on this view, the persistence of any degree of nervo-muscular power, in such cases as that already referred to, in which the Red corpuscles appeared to be entirely deficient (§ 192), the same difficulty attends *any* attempt to assign a use for them, which shall be in accordance with their well-marked importance as constituents of the Blood. And we may suppose that, in such cases, the Colourless corpuscles, although discharging the duty less perfectly, might perform it to a certain extent, as they seem to do among the Invertebrata.

211. The difficulty of precisely determining the functions of the Red corpuscles, is even surpassed by that of assigning the probable duty of the Colourless. The considerations already adduced appear to show, that the Colourless corpuscles are to be considered as cells of a lower grade than the Red; since they represent them among Invertebrated animals, and also in the incipient blood of Vertebrata; and also, because cells resembling the former (if not the very same) pass-on to develope themselves into the latter (§ 169). Still we find that this final change does not occur among the Invertebrata; and it is obvious, therefore, that even in their colourless state, the corpuscles have a function to discharge in the vital economy. Little light has yet been thrown upon this subject, by inquiry into the Chemical composition of the blood-corpuscles of the lower animals; and no means have yet been devised for obtaining the colourless corpuscles of the higher in a separate state, for the purpose of determining this. A minute sample of the blood-corpuscles of a Crab, however, examined by Prof. Graham, has been found by him to contain "a sensible quantity of iron, the proportion being perhaps as large as in red corpuscles."* Thus, then, we have evidence that the difference of hue between the two sets of Corpuscles, does not involve any considerable difference in the proportion of one of the most characteristic elements of the Red; and if it be admitted that they are both to be looked upon as having the same origin, and as differing only in their stage of development, it is manifest that no other difference can be fairly expected to exist in their contents, than that which is marked by the formation of the colouring-matter, as the final effort of their transforming power. This product, as we have seen (§ 160), constitutes but about *one twentieth* of the whole contents of the Red corpuscles.—The following observation by Mr. Newport seems to indicate, that the corpuscles of the blood of Insects (some of them in the condition of 'granule-cells,' others in that of 'nucleated colourless cells,' § 169), have an important function to perform in the elaboration of nutrient material. The 'oat shaped' corpuscles (the 'granule-cells' of Mr. Wharton Jones) are found, in the Larva, to be most numerous at the period immediately preceding each change of skin; at which time the blood is extremely coagulable, and evidently possesses the greatest formative power. The smallest number are met-with soon after the change of skin; when the nutrient matter of the blood has been exhausted in the production of new epidermic tissue.

* "Philosophical Transactions," 1846, p. 105

of the fibrin, which, from being tough, elastic, clear, uniform, and of filamentous appearance or filamentous structure, becomes less and less filamentous, softer, more paste-like, turbid, nebulous, dotted, and mingled with minute oil molecules." "After some practice," adds Mr. Paget, "one might form a fair opinion of the degree in which a patient was cachectic, and of the degree in which an inflammation in him would tend to the adhesive or to the suppurative character, by the microscopic appearance of these exudations."*—From such evidence we seem forced to the conclusion, that, whether or not the Colourless corpuscles are to be regarded in any other light than as blood-cells not yet fully developed, their multiplication is *not* (as was once maintained by the Author and others) the source of increase in the fibrinous constituent of the liquor sanguinis.† Whether the arrest of development of these corpuscles, in the abnormal conditions just referred-to, is to be attributed to an original want of capacity in their germs, or to some agency which subsequently depresses their vital power, or to the want of some material which they require for the purpose, can scarcely at present be decided; and it may be doubted whether any one of these determining causes is in action in every case, or whether each of them may not occasionally operate, either singly or in combination.

213. Turning now to those constituents of the Blood which show no indications of possessing vitality, we have first to speak of its *Albumen*. The relations which this substance bears to the living body are of the most important and fundamental character; since, as elsewhere shown (PRINC. OF GEN. PHYS.), it is the original *pabulum* at the expense of which all the solid tissues are generated, whilst it also affords the material for the production of the fibrin, the globulin, and the hæmatin of the blood itself. It appears, however, to be itself entirely destitute of formative capacity; for in no exudation which is purely serous, do we ever trace the slightest indication of organization; and its conversion into the various kinds of tissue, therefore, must be entirely due to their own power of appropriating and transforming it.‡ The great function

* "Med. Gazette," 1850, vol. xlv. p. 1015; and "Surgical Pathology," vol. i. p. 33[illegible]

† The Author cannot help still suspecting, however, that the Colourless corpuscles are not to be regarded *merely* as red blood-cells in their earlier phase of development, but that they have some special connection with the elaboration of the plastic constituents of the blood. Warned, however, by previous experience, of the danger of building conclusions upon observations of a limited and imperfect character, he refrains at present from forming any hypothesis as to the nature of that relation; merely suggesting that it is far from certain that all the bodies which pass under the designation of 'white' or 'colourless corpuscles' are of the same kind, as is shown by the fact, that cells are formed in exudations, which cannot be distinguished from the colourless cells of the blood, and which yet can scarcely be supposed to be rudimental red corpuscles; and that if some of the 'colourless corpuscles' of the blood be looked-upon as instrumental in elaborating its plastic components, whilst others are on the march of development into red corpuscles, it seems very probable that the same depressing influence which checks the latter process should also interfere with the former, and that thus an accumulation of colourless corpuscles in cachectic subjects may coincide with a diminution in the red, and at the same time with an imperfect elaboration of the fibrin of their blood.

‡ Those who maintain that Fibrin is the only organizable constituent of the blood, and that it is the immediate source of the nutrition of the tissues generally, consider that Albumen cannot be appropriated by the tissues, without first passing through the condition of fibrin. This doctrine, formerly contended for by the Author, he now abandons as inconsistent with much that we know of the history of Fibrin and of its destination in the body (§ 208); and he would rest upon the simple fact, that the first development of

in cases in which the action of the Pancreas or of the Liver is disturbed by disease of one or both of those organs.* But they are sometimes discharged in such large quantities, that it is scarcely possible thus to account for their presence; and it would seem that they must have been poured into the alimentary canal, either by the liver or by some other excreting organ which must have drawn them off from the blood. It does not seem an improbable surmise, that, in such cases, there may be an extraordinary tendency to the metamorphosis of albuminous and other azotized matters (whether furnished by the tissues or by the food) into fat, and that the excretion of this substance does in effect tend to keep down their proportion in the blood. Their occasional extraordinary accumulation in the circulating fluid (§ 192) tends to confirm this view; for it appears scarcely possible that such an enormous proportion of fat could have been derived from the food, either in the condition of fat, or in that of a saccharine compound capable of being converted into it.

215. All the other Organic compounds which have been distinctly recognized in the blood, or of whose presence in the circulating current we have inferential evidence,—sugar, lactic acid, urea, uric acid, hippuric acid, creatine, creatinine, the volatile fatty acids, and the odorous substances,—are to be considered, not as in any way subservient to the constructive changes in which Nutrition properly consists, but as products of the retrograde metamorphosis, either of the alimentary materials, or of the tissues themselves; and as on their way to be eliminated from the blood, either by the respiratory organs, or by some other part of the Excretory apparatus. And the more perfect the balance between the action of this apparatus, and the operations whereby these compounds are generated, the less will be the proportion in which they present themselves in the blood, and the greater will be the difficulty in detecting them there.

216. The uses of the various *Inorganic* compounds, which, as being uniformly present in the Blood, must be considered among its integral constituents, are not as yet by any means positively known; yet great advances have been recently made towards this knowledge, and it may be pretty certainly affirmed, that the presence of some of them has reference to the peculiar functions and conditions of the blood itself, whilst others are chiefly destined for appropriation by the tissues to whose growth it ministers. The former seems to be especially the case with the Alkaline salts; of which the *phosphate and carbonate of soda* would seem to have it for their chief purpose, to maintain the alkalinity of the blood, on which depend not merely the liquidity of its albumen, but the facility of its passage through the capillaries, and the readiness with which its combustive materials are oxidized; whilst they also increase the absorptive power of the serum for gases. So the presence of *chloride of sodium* is needed for the conservation of the organic components of the blood in their normal condition, and it also seems to be essential to the performance of many of the metamorphic and histogenetic operations to which these substances are subjected in the economy; this salt, moreover, is itself required as a component, not only of the solid tissues

* See Dr Bright's Memoir on 'Disease of the Pancreas and Duodenum,' in "Medico-Chirurg. Trans.," vol. xviii., and the Art. 'Pancreatic Disease and Fatty Discharges,' in "Brit. and For. Med. Chir. Rev.," vol. xii. p. 154.

combination with the tissue that is diseased, or with the organized product of the morbid process. Such a substance fastens upon certain spots or islands on one side of the body, leaving the surrounding parts unaffected; and precisely similar spots or islands are affected in like manner on the other side. The conclusion seems unavoidable, that, however closely one portion of skin or bone may seem to resemble another, the only parts that are *exactly* alike are those which repeat each other symmetrically on the opposite sides of the body; for, although no power of artificial chemistry may determine the difference, the chemistry of the living body makes it evident, the morbid material testing-out the parts for which it has the greatest affinity, uniting with these alone and passing by the rest. It is continually observable, moreover (as Mr. Paget has remarked), that a poison of the same kind will attack corresponding spots, not merely on the two sides of a single individual, but also on the two sides of any others who may have imbibed it into their systems. Thus the syphilitic poison has its 'seats of election' when it begins to attack the bones, fixing upon certain parts of the tibiæ and of the skull with great uniformity; and in the Hunterian Museum are the pelves of two lions, on both of which new osseous deposit has taken place (as the product of some disease resembling rheumatism in man) in a most complex and irregular pattern, this being so similar in the two, that almost every spot and line of the one is represented in the other, with an exactness only inferior to the symmetrical correspondence between the two sides of each.* It has been further pointed-out by Dr. W. Budd, as indicated by the phenomena of these diseases, that next to the parts which are symmetrically placed, none are so nearly identical in composition as those which are analogous, such as the corresponding parts of the superior and inferior extremities.—All these facts tend to demonstrate the perfect and most minute exactness of the adaptation which must exist in the state of health between the blood and all the tissues, as well as the almost inconceivable minuteness of the departure from this adaptation which may become a source of disease; and it is a sure indication of the safety with which we may found such inferences upon them, that the phenomena of symmetrical disease are most distinct, when the disordered action is most conformable, as to its character and its rate, to the normal nutrition of the structure; it being in diseases which (though dependent upon a poison in the blood) are of an inflammatory or other virulent nature, that the symmetry of the morbid change is least obvious.

218. Hence, then, we are led to the conclusion, that, as Treviranus phrased it, "each single part of the body, in respect of its nutrition, stands to the whole body in the relation of an excreted substance;" or, in other words, each part of the body, by taking from the blood the peculiar substances which it needs for its own nutrition, does thereby act as an excretory organ, inasmuch as it removes from the blood that which, if retained in it, would be injurious to the nutrition of the body generally. Thus, the phosphates which are deposited in our bones, are as effectually excreted from the blood, and as completely prevented from acting injuriously on other tissues, as are those which are discharged with the urine. The applications of this doctrine have been greatly extended by Mr.

* See Mr. Paget's 'Lectures on Nutrition, &c.' in the "Medical Gazette" for 1847, Lect. i.; and his "Lectures on Surgical Pathology," vol. i. pp. 18–23.

being supplied by the history of the evolution of the generative apparatus, and by that of the concurrent changes in other organs (especially the tegumentary) which are found to be dependent upon it, although there is no direct functional relation between them. Thus, the growth of the beard in man at the period of puberty, is but a type of a much more important change which takes place in many animals with every recurrence of the period of generative activity. This is most obvious in birds, whose plumage, at the commencement of the breeding season, becomes (especially in the male) more highly coloured, besides being augmented by the growth of new feathers, but when the sexual organs pass into their state of periodic atrophy, the plumage at once begins to assume a paler and more sombre hue, and many of the feathers are usually cast, their nutrition being no longer kept-up. It is a matter of common observation, that the deficiency of hair on the face (where this is not, as among the Asiatics, a character of race) is usually concurrent with a low amount of generative power in the male, and may be considered as indicative of it; whilst, on the other hand, the presence of hair on the upper lip and chin of the female is indicative of a tendency in the general organization and mental character towards the attributes of the male, and of a deficiency in those which are typical of the female. If, moreover, the development of the male organs be prevented, the evolution of the beard does not take place; whilst the cessation or the absence of activity in the female organs is often attended by a strong growth of hair on the face, as well as by other changes that may be attributed to the presence of some special nutritive material in the blood, for which there is no longer any other demand. This, again, shows itself yet more strongly in Birds, among which (as Hunter long since pointed-out*) it is no uncommon occurrence for the female, after ceasing to lay, to assume the plumage of the male, and even to acquire other characteristic parts, as the spurs in the fowl tribe. Moreover, it has been ascertained by the experiments of Sir Philip Egerton, that if a buck be castrated while his antlers are growing and are still covered with the 'velvet,' their growth is checked, they remain as if truncated, and irregular nodules of bone project from their surfaces; whilst, if the castration be performed when the antlers are full-grown, these are shed nearly as usual at the end of the season, but in the next season are only replaced by a kind of low conical stumps.

220. That these and similar changes in the development of organs are immediately determined by the condition of the circulating fluid, that is, by the presence or absence of the appropriate 'pabulum' for the parts in question, would further seem likely from the fact, that they may be artificially induced by circumstances which directly affect the condition of the blood. This has been shown by Mr. Yarrell,† in regard to the assumption of the male plumage by the female; and a still more remarkable and satisfactory proof is furnished by the conversion of the 'worker' larva of the Bee into a perfect 'queen,' solely through a change of diet.‡ And thus we are led to feel that Mr. Paget's doctrine of 'complementary

* 'Account of an Extraordinary Pheasant,' in "Hunter's Works," Palmer's edit., vol. iv. p. 44.

† "Philosophical Transactions," 1827.

‡ "Princ. of Comp. Phys.," § 119

germinal mass, it goes through a succession of phases, which are partly the cause, and partly the effect, of developmental changes in the organism generally. So long as the operations of Nutrition are normally carried on, the materials that are withdrawn by the several parts of the body may be considered so far to balance one another, that no *waste* is incurred from this source; and if the amount of new matter introduced be merely the equivalent of that which is required for the nutritive operations, nothing else will occasion a demand for elimination, save the products of the disintegration of the tissues, which are received back into the blood for this purpose. But it must be very rarely that this balance is precisely maintained for any length of time, since a multitude of circumstances are continually occurring to derange it; the most frequent, perhaps, being the ingestion of certain nutritive materials in greater quantity than they are required. And we then find that the excretory organs take upon themselves a supplemental action for the removal of the superfluity; the kidneys being especially charged with this duty in the case of azotized and saline matters, and the liver and lungs in regard to hydrocarbonaceous substances. It is obviously of importance, however, to overtask these organs as little as possible; and when such superfluity is becoming a source of disease, the obvious treatment is rather to prevent it from being thrown upon them for separation, by diminishing the supply of aliment generally, or of some particular article of diet, than to excite them to increased activity by stimulating medicines.

223. The self-maintaining power of the Blood is yet more shown in the phenomena of Disease; and especially in its spontaneous recovery of its normal condition, after the most serious perversions; as we see more particularly in febrile diseases of definite type (such, for example, as the Exanthemata, Typhoid, Typhus, &c.), of whose origin in the introduction of specific poisons into the blood, there is no reasonable ground for doubt. In studying the mode in which these and other 'morbid poisons' act upon the blood, and through it upon the system at large, we may derive important assistance from a previous inquiry into the history of the action of those poisonous agents, which, from their being more readily traceable by chemical analysis, can be more satisfactorily made-out. Such an inquiry has a most important bearing, also, on the *modus operandi* of medicines.—The operation of medicinal or poisonous substances for the most part depends upon the power which they possess, when introduced into the current of the circulation, of effecting some determinate change in the *chemical* and thereby in the *vital* condition, either of the components of the blood, or of some one or more of the tissues which it nourishes; and their determination to some special part or organ must be attributed to the same kind of elective affinity, as that by which the normal constituents of the blood are so determined (§ 217). Now of nearly all these substances it may be said, that the system, if left to itself, tends to free itself from them, provided *time* be allowed for it to do so; and that, when death results from their introduction into it, the fatal result is to be attributed to the fact, that the disorganization of structure and disturbance of function are too rapid and violent, to allow the eliminating processes to be set in efficient operation. When smaller doses are taken, their effects are evanescent, unless the abnormal action to which

the effects of a dose of Alcohol, even when this is large enough to produce insensibility; recovery from them being merely a question of time, provided that the state of torpor, produced by the action of this poison on the centre of the respiratory movements, be not so profound as to occasion Asphyxia, or that death do not result (as sometimes happens when the poison is taken in a state of concentration) from the immediate *shock* to the nervous system. Now the quantity of alcohol which passes-off by the ordinary excretions is extremely slight; in fact, this substance can seldom be detected in them. But there can be no reasonable doubt that the elimination of the alcohol is due to its oxidation whilst passing through the circulating system, so that it is excreted by the lungs in the form of carbonic acid and water; and if confirmation of this view were needed, it is afforded by the *tolerance* of large doses of alcohol, which is shown when it is subjected with peculiar rapidity to the combustive operation, as during continued exposure to severe cold or prolonged muscular exertion, or in the exhaustion of wasting diseases when no other combustive material remains in the body. The same explanation is obviously applicable to the parallel phenomena which present themselves in the action of Opium, Strychnia, Prussic acid, &c. With all these, also, the question of life or death is one of *time;* for if the fatal result do not speedily follow the absorption of the poison into the blood, the patient gradually recovers from its effects; and the most effectual treatment consists in the artificial maintenance of the respiratory movements, which the influence of these poisons upon the nervous centres might otherwise suspend. These poisons cannot be-detected in the circulating fluid by their sensible or chemical characters, if a short interval has elapsed subsequently to their absorption; thus it has been found by Dr. Lonsdale that the odour of prussic acid cannot be perceived in the blood or in the cavities, when life had been prolonged beyond 15 minutes, although, when death took place within a shorter time, the poison might be detected in the body by its odour alone for eight or nine days afterwards; and the presence of morphia ceases to be recognizable by the ordinary chemical tests, within a short time after it has been taken into the circulating current.—Even with regard to certain poisons of this unstable class, however, there is evidence that they pass into the urine and are thus eliminated, without undergoing any change that impairs their physiological action; this evidence being afforded in the effects of the re-ingestion of the urine, either by the individuals themselves, or by others. A very curious example of this kind is afforded by the intoxicating fungus, *Amanita muscaria*, which is used by some of the inhabitants of the north-eastern parts of Asia, in the same manner as alcoholic liquors by other nations. Its effects, like those of other excitants, have a limited duration; for a man who is intoxicated by it one day, 'sleeps himself sober' by the next. His restoration is due, however, not to his repose, but to the elimination of the poison which takes place during the interval; for if he drink a cup of his urine the next morning, he is yet more powerfully intoxicated than he was the preceding day; and this fluid has the same effect upon any other individual, into whose urine the active principle then passes; so that, according to the testimony of travellers, the intoxicating agent may be transmitted in this manner through five or six persons, a small stock at the commencement thus serving to maintain a

toxic agents whose action has been previously examined, and that of the morbid poisons we are now considering; for whilst the former possess a certain definite action, the intensity of which (*cæteris paribus*) is proportionate to the quantity that is in operation, and which is usually determined, in virtue of the 'elective affinity' already spoken-of, to some particular organ or tissue,—the latter act primarily upon the blood, influencing the system at large through the changes which they produce in its constitution; and their potency depends rather upon the susceptibility of the blood to their peculiar influence, than upon the quantity of the poison that may be introduced into it.

226. Of the existence of such susceptibility, as a 'predisposing cause' of *Zymotic** disease, there cannot be the slightest doubt. In the case of the Exanthemata and Hooping-cough, we see that it is congenital, and is usually removed by the occurrence of one attack of the disease (although this is not a uniform protection); but the liability even to these varies greatly in different individuals, and at different times in the same individual. And with regard to other zymotic diseases, the liability to which is not thus limited, all extended observation concurs in showing that it is augmented by anything which tends to depress the vital powers of the system, and more particularly by any cause which obstructs the due purification of the blood, by the elimination of the products of decomposition. Thus, it will be shown hereafter (§ 330, 331), that no antecedent condition has been found more efficacious in augmenting the fatality of Cholera, than *overcrowding;* which compels those who are subjected to it, to be constantly breathing an atmosphere not only charged with carbonic acid, but laden with putrescent emanations; and which thus favours the accumulation of decomposing matter in the blood, which serves as the most appropriate soil for the seeds of the disease. And what is true of Cholera has been found to be true of Zymotic diseases in general; the very same fermentible matter in the blood serving for the development of almost any kind of zymotic poison that may be received into the system, whether from the atmosphere, or from the bodies of those who have already been subjects of the disease.—Now that what has been here spoken of as 'fermentible matter,' is not a mere hypothetical entity, but has a real material existence, appears from this consideration; that in all those conditions of the system in which we know that decomposition is going-on to an unusual extent, and in which there is a marked tendency to putrescence in the excreted matters, we witness such a peculiar liability to zymotic diseases, as clearly indicates that the state of the blood is peculiarly favourable to the action of the zymotic poison. This is pre-eminently the case in the puerperal state, in which the tissue of the uterus is undergoing rapid disintegration, its vital force having been expended (§ 349); for there is now abundant evidence, that the contact of decomposing matters which would be innocuous at other times, is capable of so acting upon the blood of the parturient female, as to induce that most fatal *zymosis* which is known

* The term *zymotic* is a very convenient designation, which, originally suggested by Dr W. Farr, has of late gained general currency, for that class of diseases whose phenomena may be attributed to the operation of a morbid poison of the nature described above; this operation bearing a strong analogy to that of 'ferments.'

seem distinctly able to trace the operation of morbid poisons circulating in the blood; for there are numerous other maladies, of whose origin in a like condition there can be no reasonable doubt; and these are in some respects more closely analogous than the preceding, to the disordered states induced by the introduction of toxic agents. For in those of which we have now to speak, the action is destitute of any analogy to fermentation, and its potency is strictly proportionate, in each case, to the amount of the dose that is in operation. Here, too, we have a connecting link afforded by those disordered states of the system, which depend upon an undue accumulation of poisons normally generated within it, in consequence of some obstacle to their elimination. Thus, the train of symptoms which is consequent upon the retention of urea in the blood, so much resembles that occasioned by the ingestion of opium, as to have actually been mistaken for it; and is as true an instance of 'poisoning,' as if urea had been injected into the blood-vessels. So, in the asphyxia which is produced by any obstruction to the extrication of carbonic acid through the lungs, the subject of it is as much 'poisoned,' as if he had inhaled carbonic acid from without. Again, the retention of the uric acid, biliary matter, lactic acid, and other substances which are normal products of the waste or disintegration of the body, is capable of becoming a source of morbid action in the system generally; and the evil is of course increased, when (as frequently happens) augmented production is concurrent with imperfect elimination. But perversions of the ordinary disintegrating processes are also far from being uncommon, whereby, instead of the substances already referred to, other products are engendered, whose presence in the circulating current gives rise to trains of symptoms altogether different. Of this class we seem to have an example in gout and rheumatism, the *materies morbi* of which diseases, though probably not identical with lithic and lactic acids, would seem to be formed from the decomposing matters which might normally have generated them. There can be no doubt, again, that many chronic diseases of nutrition are attributable to a similar cause; this being indicated by the *symmetrical* mode in which they affect the particular parts whose condition is altered (§ 217).

228. In all cases, therefore, one of the first questions which the intelligent Practitioner will feel called-upon to decide, is, whether the malady he has to treat originates in the state of the Blood, or in a disorder purely local; and, if he feel justified in referring it to the blood, whether it merely depends upon an alteration in the proportion of its normal constituents, as in plethora and simple anæmia, or whether its phenomena imply the presence of some toxic substance in the circulating fluid. If the former be his conclusion, he has then to endeavour to rectify the excess or the deficiency, by reducing the former, or by supplying the latter; as when he bleeds and prescribes low diet for Plethora, and employs iron and generous living in Anæmia. But it is his duty to take care that his means are appropriate to his ends; and especially to abstain, when endeavouring to draw-off an excess of one constituent, from doing serious injury by reducing another which may be already below par, and of which the presence may be essential to enable the system to resist the further progress of the malady. Thus, as we have seen, blood-letting *has no* decided effect in lowering the proportion of *fibrin* in the blood, whilst it *has* a

they have the power of multiplying themselves within the body; thus for example, when small-pox has been communicated by the inoculation of an excessively minute portion of the virus, hundreds or thousands of pustules are generated, each of them charged with a poison equally potent with that from which they originated. It is to this multiplication, that the extension of zymotic diseases, by communication between individuals affected with them and healthy subjects, is chiefly due; and the question of the 'contagion' or 'non-contagion' of any particular disease of this class is, therefore, essentially that of the multiplication or non-multiplication of the poison in the human body. This multiplication of certain zymotic poisons is a yet stronger point of analogy to the action of 'ferments,' than that which is afforded by the violence of the changes they induce, when compared with the amount in operation. Some of these poisons are of such potency, that, in however minute a quantity they are introduced, they will change the whole mass of the blood in a few minutes; and will act indiscriminately on all individuals alike; this is the case, for example, with the venom of serpents. On the other hand, there are many (as already remarked) which seem to require the presence of some special fermentable matter in the blood (§ 226). And between these might probably be established a regular gradation,—from those most 'pernicious' forms of malarious poison, which derive their potency from the intensity of vegetable decomposition under the influence of a high temperature, or those 'malignant' types of typhoid poison, which owe their special intensity to animal putrescence engendered by filth and overcrowding, both of these attacking a very large proportion of those who are exposed to them,—to those milder forms of zymotic poisons, which, though derived from the same sources with the preceding, act with so much less of uniformity upon different individuals, that we can scarcely fail to recognise, as a 'predisposing cause,' or rather as a necessary concurrent condition, the presence of some readily-decomposable matter in the blood. The long-continued action of these poisons, in their milder forms, seems itself capable of inducing this condition; thus, a healthy person who settles in an aguish country, may remain free from intermittent fever for a considerable time, but his health gradually deteriorates, and at last he becomes the subject of the disease, which would have much earlier attacked him, if his blood had been brought into the 'fermentible' state by irregularity of diet, over-exertion, &c., and the same may be observed in the case of those long exposed to the poison of typhoid or other fevers, which specially locates itself in animal miasmata, if it be not actually engendered by them.

231. In some of the diseases of this class, the change in the qualities of the Blood produced by the introduction of the poison, is such as to give it a morbid action on certain organs or tissues only; their phenomena in this respect corresponding with those of ordinary poisons, and of the toxic diseases previously noticed. Such may be said of vaccinia, gonorrhœa, primary syphilis, &c., in which the general functions of the body seem to be disturbed chiefly or solely through the local disorder. It may happen that, even where a specific poison is present in the blood, it may not be potent enough to manifest itself in any disordered action, either general or local, until the depressed state of the nutrition of some part or organ renders it more susceptible of a further perversion; thus it

diffuse cellular inflammation; some had inflammation of the lymphatic glands of the head, axilla, and lower extremities; one had severe idiopathic erysipelas of the head and neck; another had phlegmonous erysipelas of the hand and arm after an accidental wound; others had low fever with or without enlargement of glands. Finally, the disease took the form of mumps, which affected almost everybody on board. The epidemic lasted from May to July (the winter in the southern hemisphere), the ship being at sea during the whole time. The local determination of a morbid poison may frequently be regarded as one of the means whereby the blood and the system at large are freed from its action. Of this, again, we have a most characteristic example in the Exanthemata: for it is a matter of constant observation, that the constitutional symptoms, especially fever and delirium, are most severe *before* the cutaneous eruption comes out; that there is much greater danger to life, when the eruption does not develope itself fully; and that its premature repression induces a return of the severer constitutional affection.* So in Syphilis and Cancer (as Mr. Paget remarks), the severest defects or disturbances in the whole economy may coexist with the smallest amounts of specific local disease; and it has been laid-down as a general law by Dr Robert Williams, "that when a morbid poison acts with its greatest intensity, and produces its severest forms of disease, fewer traces of organic alterations of structure will be found, than when the disease has been of a milder character."†

232. In nearly all the Toxic diseases of the zymotic class, there is a natural tendency to the self-elimination of the poison and of the products of its action on the blood, either by the operation of the ordinary excretory organs, or by the peculiar local actions just adverted-to; and this process takes place in many instances with such regularity, that not only the period which it will altogether require, but each of those successive epochs which mark the stages of development and metamorphosis in the poison and in the products of its action, may be almost exactly predicted. There is not, in fact, a more remarkable indication of the 'Life of the Blood,' than is afforded by its extraordinary power of self recovery, after having undergone the excessive perversion which is consequent upon the introduction of the more potent Zymotic poisons; and every philosophical physician is ready to admit, that it is to this 'vis medicatrix naturæ,' rather than to any remedial agency which it is in his power to apply, that he must look for the restoration of his patient. The very nature of the action of zymotic poisons upon the blood, seems to forbid the expectation of our being able to neutralize or check that action by antidotes; and the objects of treatment wholly lie, therefore, in promoting the elimination of the morbific matters thus engendered, in

* It may be objected to this general statement, that, as the severity of Small-pox usually bears a constant ratio to the amount of the cutaneous eruption, this cannot be regarded as relieving the blood of a poisonous impregnation. But it is to be borne in mind, on the one hand, that the confluence of the pustules greatly impedes the normal functions of the skin, whereby the constitutional disturbance is most seriously aggravated, their suspension, if complete, being alone adequate to destroy life; and besides this, the excessive severity of the eruption is an indication that the poison has either possessed an extraordinary potency, or has found within the blood a material peculiarly favourable to its development.

† "Elements of Medicine," vol. i. p. 12.

in other Vertebrated animals, there is a regular and continuous movement of the nutritive fluid through the sanguiferous vessels; and upon the maintenance of this, the activity of all parts of the organism is dependent. In common with Birds and Mammals, again, Man has a Respiratory circulation entirely distinct from the Systemic; all the blood which is returned from the body being transmitted to the lungs, and being brought back to the heart again, before it is again sent-forth for the nourishment of the tissues and for the maintenance of their functional activity. The Heart is placed at the junction of these two distinct circulations which may be likened to the figure 8; and it may be said to be formed by the fusion of two distinct organs, a 'pulmonary' and a 'systemic' heart: for its right and left sides, which are respectively appropriated to these purposes, have no direct communication with each other (in the perfect adult condition, at least), and seem merely brought-together for economy of material.* Each system has its own set of Arteries or efferent vessels, and of Veins or afferent trunks; these communicate at their central extremity by the Heart, and at their peripheral extremity by the Capillary vessels, which are nothing else than the minutest ramifications of the two systems, inosculating into a plexus.—Besides the systemic and pulmonary circulations, however, there is another which is no less distinct, although it has not an impelling organ of its own. This is the 'portal' circulation, which is interposed between the venous trunks of the abdominal viscera and the Vena Cava, for the purpose of distributing that blood through the Liver, in which organ its newly-absorbed materials undergo assimilation (§ 132), whilst its excrementitious matters are separated by the secreting process. The Vena Portæ, which is formed by the convergence of the gastric, intestinal, splenic, and pancreatic veins, subdivides again like an artery, so as to form a capillary plexus which extends through the whole substance of the liver; and the Hepatic vein, collecting the blood from this plexus, conveys it into the Vena Cava. Thus the *portal* circulation is grafted (so to speak) upon the *general* circulation, in precisely the same mode as the respiratory circulation is grafted upon it in Mollusca and Crustacea; and if the 'sinus' of the vena portæ had possessed contractile muscular walls, it would have ranked as the proper heart of the portal system. The really arterial character of the Vena portæ is well shown by comparing it with the Aorta of Fishes; which is formed by the convergence of the branchial veins, and then distributes the blood which it has received from them to the body generally.

234. That the movement of the Blood through the arterial trunks and the capillary tubes, is, in Man, and in other warm-blooded animals, chiefly dependent upon the action of the Heart, there can be no doubt whatever. It can be easily shown by experiment, that if the arterial current be checked, the capillaries will immediately cease almost entirely to deliver the blood into the veins, and the venous circulation will be consequently arrested. And it has also been proved, that the usual force of the Heart is sufficient to propel the blood, not only through the arterial tubes, but through the capillaries, into the veins; since even a less force will serve

* At an early period of fœtal life, as in the permanent state of the Dugong, the heart is so deeply cleft, from the apex towards the base, as almost to give the idea of two separate organs.

connecting isthmus be composed of tendon, even though this be a portion of the auriculo-ventricular ring, which has been supposed by some to be peculiarly efficacious in this conduction.—That the irritability of the Heart is not dependent upon the Cerebro-spinal system, appears not merely from the manifestation of it when the organ is altogether removed from the body; but also from the fact, that if the flow of blood through the lungs be kept-up by artificial respiration, the heart's action will continue for a lengthened period, even after the Brain and Spinal Cord have been removed, and when animal life is, therefore, completely extinct. Hence we see that the Irritability of this organ must be an endowment properly belonging to itself, and not derived from that portion of the Nervous System (§ 238). Like the contractility of other muscles, it can only be continuously sustained by a supply of Arterial blood to its own tissue (See PRINC. OF GEN. PHYS.). It is much less speedily lost in cold-blooded animals, however, than in warm-blooded; the heart of the Frog, for example, will go on pulsating for many hours after its removal from the body; and it is stated by Dr. Mitchell,* that the heart of a Sturgeon, which he had inflated with air, continued to beat, until the auricle had absolutely become so dry, as to rustle during its movements. It has further been shown by Mr. Tod, that the irritability of the heart is of great duration after death in very young animals; which, as was long since demonstrated by Dr. Edwards, agree with the cold-blooded Vertebrata in their power of sustaining life, for a lengthened period, without oxygen.

236. It is difficult to account for the long continuance of the alternate contractions and relaxations of the muscular parietes of the Heart, after all evident stimuli have ceased to act upon it; and many theories have been offered on the subject, none of which afford an adequate explanation. The extraordinary tendency to *rhythmical* action, by which the heart is distinguished from nearly all other muscles, is shown by the fact, that not only do the entire hearts of cold-blooded animals continue to act long after their removal from the body, but even separated portions of them will contract and relax with great regularity for a long time. Thus the auricles will persist in their rhythmical action, when cut-off above the auriculo-ventriculo rings, and the apex of the heart will do the same, when separated from the rest of the ventricle. The stimulus of the contact of blood with the lining membrane of the heart, to which its regular actions have been commonly referred, can have no influence in producing such movements; nor does it appear that the contact of *air* can take its place; since, as Dr. J. Reid has shown, the rhythmical contractions of the heart of a frog will continue *in vacuo*.† Nor is there any evidence that

* "American Journal of the Medical Sciences," vol. vii. p. 58; see also Prof. Dunglison's "Human Physiology," 7th edit., vol. ii. p. 149.

† "Cyclopædia of Anatomy and Physiology," vol. ii. p. 611.—This experiment has been since repeated by Prof. Tiedemann ("Muller's Archiv.," 1847) and by Drs. Mitchell and Bache (Prof. Dunglison's "Human Physiology," 7th Edit., vol. ii. p. 150) with a different result; the pulsations being speedily brought to a stand by the exhaustion of the air, and being renewed when it was re-admitted. This, however, does not invalidate the positive fact, that the pulsation *may* continue *in vacuo*, which proves that the stimulus of air cannot be its maintaining power; and only shows that the presence of oxygen is essential to the continuance of the heart's movements, as to muscular action in general.

Spinal centres, too, that the influence must originate, which is exerted by excessive Mental Emotions, in depressing or even checking the Heart's action, and in hence producing a state of the general system closely resembling that which results from severe bodily injury.

239. It has been asserted by Valentin and other experimenters (though many more have obtained none but negative results), that mechanical irritation of the Pneumogastric nerves, especially at their roots, has a tendency to *accelerate* the heart's action, or to *re-excite* it when it has come to a stand. On the other hand, it is certain that these nerves may serve as the channel of an influence of a very opposite character; for the experiments of MM. Weber, which have been repeated by many others with the same effect, have shown that the movements of the Heart may be immediately *arrested* by the transmission of the electric current from a rotating magnet, either through the Spinal Cord, or through the Pneumogastrics divided at their origin; the same irritation, however, applied to a single one of the Vagi, produced no effect.* Hence it is probable that the influence of sudden and violent injury to the Cerebro-spinal system, may be conveyed through these trunks, as well as through the Sympathetic nerves.—Admitting, then, that some influence is exerted upon the Heart's action by the Cardiac branches of the Pneumogastric, it remains to inquire whether that influence be essential to its movements; and whether these nerves form the channel through which they are affected by emotions of the mind, or by conditions of the bodily system. In regard to the first point, no doubt can be entertained; since the regular movements of the heart are but little affected by section of the Pneumogastrics. With respect to the second, there is more difficulty; since the number of causes which may influence the rapidity and pulsations of the heart, is very considerable. For example, when the blood is forced-on more rapidly towards the heart, as in exercise, struggling, &c., its contractions are rendered more frequent; and when the current moves-on more slowly, as in a state of rest, their frequency becomes proportionably diminished. If the contractions of the heart were not thus in some degree dependent upon the blood, and their number were not regulated by the quantity flowing into its cavities, very serious and inevitably-fatal disturbances of the heart's action would soon result. That this adjustment takes place otherwise than through the medium of the nervous centres, is evident from the fact, that, in a dog, in which the Pneumogastric and Sympathetic had been divided in the neck on each side, violent struggling, induced by alarm, raised the number of pulsations from 130 to 260 per minute.† It is difficult to ascertain, by experiments upon the lower animals, whether simple emotion, unattended with struggling or other exertion, would affect the pulsation of the heart, after section of the Pneumogastrics; but when the large proportion of the Sympathetic nerves proceeding to this organ is considered, and when it is also remembered that irritation of the roots of the upper cervical nerves stimulates the action of the heart through these, we can scarcely doubt that both may serve as the channels

* "Archives d'Anat. Génér., et de Physiol.," Jan. 1846; and "Wagner's Handworterbuch," band iii. abth. 2, Art. "Muskelbewegung."

† See Dr. J. Reid's "Anat. Phys. and Path. Researches," p. 170.

of movement to the limbs with which they remain in connection. But this hypothesis does not give any real solution to the difficulty; for in every case of true 'reflex' action, the movement is excited by a stimulus, and no rhythmical succession of movements can be thus excited, save by the successive recurrence of stimuli at regular intervals, as in the act of Respiration. It is the continuance of activity after all conceivable sources of stimulation have been withdrawn, which constitutes the real difficulty of the case; and if the operation of such stimuli be admitted as the sources of *reflex* action, they may with equal propriety be regarded as *directly* acting upon the contractile fibre,—which, as already shown, is much more amenable to such direct excitation, than it is to nervous influence; and preserves its capacity for being impressed by the former, during a much longer period than it remains capable of responding to the latter. Moreover, the fact that this movement is seen to commence in the embryonic heart, when as yet its parietes consist of ordinary cells, and no nervous structure exists either in its own substance or in the body at large, stands in complete opposition to the idea, that nervous force is in any way concerned in maintaining this rhythmical action.

242. A more satisfactory mode of accounting for the rhythmical movements of the Heart, appears to the Author to lie in regarding them as an expression of the peculiar vital endowments of its Muscular tissue. For so long as this tissue retains its integrity, and the other necessary conditions are supplied, so long does an alternation of contraction and relaxation appear to be the characteristic and constant manifestation of its vital activity; just as ciliary movement is in cells of one class, and secreting action in those of another.—But it may be said that, in attributing to the muscular structure of the heart a self-moving power, we really only throw-back the question into the obscurity from which the Physiologist has sought to draw it.* Such is far from being the case, however, if it can be proved that this self-moving power is nothing else than an exertion of ordinary Muscular Contractility under peculiar conditions, and that analogous phenomena present themselves in other cases.† Now it is shown elsewhere (PRINC. OF GEN. PHYS.), that the contraction of *any* Muscle upon the application of a stimulus, must be attributed to an exercise of Vital Force engendered by previous acts of Nutrition. The stimulus is not the source of the force, but only supplies some condition which is requisite for its manifestation; just as the application of the discharger to the Leyden jar (which has been charged by the previous action of the Electrical machine) liberates, so to speak, its pent-up electricity, and allows this to display itself as an active force. Now, just as the Leyden jar may be so charged with electricity, as to *dis*charge itself

* In so far as it attributes the Heart's action to causes originating in itself, this doctrine may be stigmatized as nothing else than the old notion of the inherent 'pulsific virtue' of the organ, so happily ridiculed by Molière and Swift. But there is really just the same difference between the two, as between the doctrine of Vital Forces, which it has been the Author's object to unfold in this and the companion Treatises, and the old notion of the 'vital principle' which was held to account for everything not otherwise explicable.

† It cannot be too constantly borne in mind, in this and other instances, that to *explain* a phenomenon in Physiology or in any other science whatever, is nothing else than to show that it is conformable to some general *law*, and that it is thus a result of some previously recognized *cause*, which is common to it with a number of other previously-observed phenomena. (See Mr. John Mill's "System of Logic," book iii. chap. xii.)

collapse of the arteries. The contraction of the Ventricles, and that of the Auricles, alternate with one another; each taking place (for the most part, at least), during the dilatation of the other. But there is a period during which the Auricles and Ventricles of both sides are dilating together. This occurs during the first part of the Ventricular diastole; for at the conclusion of the systole, the Auricles are far from being completely filled, and they go-on receiving an additional supply from the great Veins (a portion of which, however, passes at once into the Ventricles) until after the middle of the Ventricular diastole, by which time they become fully distended and immediately contract. The contraction of the Auricles is synchronous, therefore, with only the second stage of the Ventricular diastole; and their dilatation is going-on during the whole period of the Ventricular systole. Thus whilst the entire period that intervenes between one pulsation and another, is nearly equally divided between the systole and diastole of the Ventricles, the division is very unequal as regards the Auricles; scarcely more than one-eighth of the whole being occupied in their contraction, and the remainder being taken up by their dilatation. The following tabular view will perhaps make the relations of the several parts of this series more intelligible:—

	Auricles.	Ventricles.	
$\frac{7}{8}$	Dilatation	Contraction.	$\frac{4}{8}$
	Continued Dilatation.	First stage of Dilatation	$\frac{4}{8}$
$\frac{1}{8}$	Contraction.	Second Stage of Dilatation.	

245. In the *systole* of the Ventricles, their surface becomes rugous; the superficial veins swell; the carneæ columnæ of the left ventricle are delineated; and the curved fibres of the conical termination of the left ventricle, which alone constitutes the apex of the heart, become more manifest.* During their contraction, the form of the Ventricles undergoes a very marked change, the apex of the heart being drawn-up towards its base, and its whole shape becoming much more globular. The movement of the apex, however, is by no means a simple elevation; for, owing to the peculiar arrangement of the fibres of this part of the heart, it is made to describe a spiral curve from right to left, and from behind forwards. It is to this change in the *form* of the heart, and in the position of its apex, rather than to change in the *place* of the organ as a whole, that we are to attribute its *impulse* against the parietes of the chest; for if any advance and recedence do take place, from the various causes which have been assigned by different observers (such as the pressure of the blood in the direction opposite to that of the orifices through which it is being impelled, the tendency of the aorta to straighten itself when distended with blood, and the elastic recoil of the parts about the base of the heart), this must be extremely trifling in its amount, since all these causes require distension of the organ with blood for their operation, and the tilting-forward of the lower part of the heart still ensues when its apex has been cut-off, and when no such tension can be exercised.—The *diastole* of the ventricles, according to Cruveilhier (loc. cit.), has the rapidity and energy of an active movement; triumphing over

* See the account given by M. Cruveilhier of a remarkable case of Ectopia Cordis, in "Gazette Medicale," Août 7, 1841.

247. There are, however, some important differences in the structure and functional actions of the two divisions of the Heart, which should be here adverted to.—The walls of the *left* Ventricle are considerably thicker than those of the *right;* and its force of contraction is much greater. The following are the comparative results of M. Bizot's measurements,* taking the average of Males from 16 to 79 years:—

	Base.	*Middle.*	*Apex.*
Left Ventricle . .	$4\frac{1}{4}$ lines	$5\frac{1}{4}$ lines	$3\frac{3}{4}$ lines.
Right Ventricle . .	$1\frac{13}{16}$ lines	$1\frac{1}{8}$ lines	$1\frac{1}{20}$ lines.

In the Female, the average thickness is somewhat less. It will be seen, that the point of greatest thickness in the *left* Ventricle is near its middle, while in the *right*, it is nearer the base. The thickness of the former goes-on increasing during all periods of life, from youth to advanced age; whilst that of the right is nearly stationary. The *left* Auricle is somewhat thicker than the *right;* the average thickness of the former being, according to Bouillaud, a line and a half, whilst that of the latter is only a line. In regard to the relative capacities of the right and left cavities, much difference of opinion has prevailed. The *right* Auricle is generally allowed to be somewhat more capacious than the *left;* and the same is commonly taught of the *right* Ventricle. So much fallacy may arise, however, from the peculiar condition of the animal at the moment of death, that this is not easily proved, and is indeed by no means certain.—The average capacity of the cavities may be estimated, in the full-sized Heart, at about three ounces; that of the Auricles being probably a little less; and that of the Ventricles a little greater. It has been shown that the Ventricles receive more blood from the Auricles, than the latter could transmit to them by simply emptying themselves once.—There is a well known anatomical difference between the auriculo-ventricular valves on the two sides, which has given rise to the diversity of name; and this seems, from the researches of Mr. King,† to be connected with an important functional difference. The Mitral valve closes much more perfectly than the Tricuspid; and the latter is so constructed as to allow of considerable reflux, when the cavities are greatly distended. Many occasional causes tend to produce an accumulation of blood in the venous system, and in the right side of the Heart; thus, any obstruction to the pulmonary circulation, cold, compression of the venous system by muscular action, &c., are known to favour such a condition. This is a state of peculiar danger, from a liability which over-distension of the Ventricular cavity has, to produce a state of muscular paralysis; and in the structure of the Heart itself, there seems to be a provision against it. For, when the ventricle is thus distended, the Tricuspid valves do not close properly; and a reflux of blood is permitted, not only into the Auricle, but also (through the imperfect closure of their valves under the same circumstances) into the large veins. This is proved by the fact, several times observed by Dr. J. Reid in his experiments upon Asphyxia, &c., that when the action of the right ventricle had ceased from over-distension, he could frequently re-excite it, not merely by puncturing its walls, but by making an opening

* "Mem. de la Soc. Médic. d'Observation de Paris," tom. i.
† "Guy's Hospital Reports," vol. ii.

evident from the fact, that it may still be heard when the heart is contracting out of the body, or when the impulse cannot take place.

b. That the sound is partly *muscular*, that is, produced in the act of muscular contraction (probably by the friction of the particles of the muscle against each other, see PRINC OF GEN. PHYS.), would appear from the fact, that it may be still perceived after the heart has been removed from the body and completely drained of its blood.* But that this is not its only source, is shown by the great diminution in its intensity, which is observable under such circumstances.

c. That the sudden *tension* of the auriculo-ventricular *valves*, with the reflux of the blood against them, at the commencement of the ventricular systole, is a cause of sound, would seem to be indicated by the analogy of the semilunar valves; and an experiment by Valentin,† in which a sound in some degree resembling the first sound of the heart was produced by the impulse of fluid against a tense membrane, has been adduced in confirmation of this view. But it is to be borne in mind, that these valves cannot close-together with the same suddenness as do the semilunar, being restrained by the spring-like tension of the carneæ columnæ; and, moreover, even admitting a sound to be produced by their closure, such a sound would be momentary, and would not possess the prolonged character of the true first-sound. Still it is not improbable that the tension of these valves serves to augment by resonance the sounds produced in other ways.

d. That the *rush of blood* through the narrowed orifices of the great arterial trunks is really a cause of sound, is indicated by the results of experiments made upon tubes out of the body, and upon large blood-vessels through which the blood is circulating; for any diminution of the calibre of a tube through which fluid is rapidly moving, gives-rise to a continuous murmur. And that this cause is in operation in the heart, is specially indicated by the observations of Cruveilhier upon the case already cited; for he noticed that (the effect of the impulse being there in abeyance) the greatest intensity of the first sound was, like that of the second, at the base of the heart, in the region from which the great vessels originate; whilst he could discover no production of sound in the region of the auriculo-ventricular valves.

e. Lastly, that the *collision* of the particles of the blood with each other, and with the tense muscular parietes of the heart, together with its movement over the inequalities of the internal surface of the ventricle, will become a cause of sound, may be suspected from what happens elsewhere, and more especially from the production of a very distinct sound by the movement of blood in the interior of an aneurism;‡ but that this cause, if it have a real existence, is much inferior in potency to the preceding, appears from the fact that it cannot be distinguished from it; and that, neither separately nor combined, do they give a sufficient account of the phenomenon, is obvious from the persistence of a sound after the heart has been completely emptied of its blood.

250. It is only by thus regarding the *first sound* as made up by *several*

* See the 'Report of the London Committee upon the Sounds of the Heart,' in the "Trans. of Brit. Assoc.," for 1836

† "Lehrbuch der Physiologie," band i. p. 427.

‡ See the 'Report of the Dublin Committee of the British Association,' loc. cit.

prussiate of potash into one part of the system, and drawing blood from another. He states that he detected this salt, in blood drawn from one of the jugular veins of the Horse, within 20 or 30 seconds after it had been introduced into the other; in which brief space the blood must have been received by the heart, must have been transmitted through the lungs, have returned to the heart again, have been sent through the carotid artery, and have traversed its capillaries. From experiments of a similar nature upon other veins, he states that the salt passed from the jugular vein into the saphena in 20 seconds; into the masseteric artery, in from 15 to 20 seconds; into the external maxillary artery, in from 10 to 25 seconds; and into the metatarsal artery, in from 20 to 40 seconds.* These experiments have been fully confirmed by those of Poisseuille,† and also by those of Mr. Blake;‡ the latter of whom varied them by employing different substances, and took other precautions against sources of fallacy. At an interval of 10 seconds after having injected a solution of nitrate of baryta into the jugular vein of a horse, he drew blood from the carotid artery of the opposite side; after allowing this to flow for five seconds, he substituted another vessel, which received the blood that flowed during the 5 ensuing seconds; and the blood that flowed after the 20th second, by which time the action of the heart had stopped, was received into a third vessel. These different specimens were carefully analysed. No trace of baryta could be detected in the blood which had escaped from the artery between the 10th and the 15th second after the injection of the poison; but in that which was drawn between the 15th and the 20th second, the salt was found to be present, and in greater abundance than in the blood which had subsequently flowed. Moreover, the coincidence between the cessation of the Heart's action, and the diffusion of the salt through the arterial blood, bear a striking correspondence; and it may be hence inferred, that the arrestment of its muscular movement is due to the effect of this agent upon its tissue, when immediately operating upon it, through the capillaries of the coronary artery.—This conclusion is borne-out by a variety of other experiments; which show that the time of the agency of other poisons that suddenly check the Heart's action (which is the especial property of *mineral* poisons), nearly coincides, in different animals, with that which is required to convey them into the arterial capillaries. And it seems to derive full confirmation from the fact, that poisons, which act locally on other parts, give the first indications of their operation, in the same period after they have been introduced into the venous circulation. Thus, in the Horse, the time that is required for the blood to pass from the jugular vein into the capillary terminations of the coronary arteries, is 16 seconds, as is shown by the power of nitrate of potass to arrest the Heart's action within that time; and nitrate of strychnia, injected into a vein, gave the first manifestation of its action on the Spinal Cord, in precisely the same number of seconds. In the

* Although attempts have been made to invalidate the inference which seems inevitably to flow from these experiments, in regard to the rate of the circulation, by attributing the transmission of the salt to the permeability of the animal tissues, yet it has never been shown that even prussiate of potash (which is probably at least as transmissable through such a channel, as any other salt) can thus find its way from one part to another, with a rapidity at all proportional to this.

† "Ann. des Sc. Nat.," 1843, Zool., tom. xix. p. 32.

‡ "Edinb. Med. and Surg. Journal," Oct., 1841.

b. The difference caused by *Sex* is very considerable, especially in adult age; it appears from the inquiries of Dr. Guy,* that the pulse of the adult Female ordinarily exceeds in frequency the pulse of the adult Male, at the same mean age, by from 10 to 14 beats in a minute.

c. Many of the observations upon the effect of *Stature* upon the pulse are invalidated by the neglect of other conditions in making them; it is affirmed by Volkmann, however, that a tolerably definite ratio exists, the pulse being *cæteris paribus* less frequent as the stature is greater; so that if the pulse of a man of 5½ feet high were 70 per minute, that of a man of 6 feet would be 66·7, and that of a man of 5 feet, 73·8.†

d. The effect of *Muscular Exertion* in raising the pulse is well known; as is also the fact, which is one exemplification of it, that the pulse varies considerably with the *posture* of the body. The amount of this variation has been made the subject of extensive inquiry by Dr. Guy; and the following are his results. In 100 healthy Males, of the mean age of 27 years, in a state of rest, the average frequency of the pulse was, when standing 79, when sitting 70, and when lying 67, per minute. Several exceptions occurred, however, to the general law; and when these were excluded, the average numbers were, standing 81, sitting 71, and lying 66; so that the difference between standing and sitting was 10 beats, or 1-8th of the whole; the difference between sitting and lying was 5 beats, or 1-13th of the whole; and the difference between standing and lying was 15 beats, or 1-5th of the whole. In 50 healthy Females of the same mean age, the average pulse when standing was 89, when sitting 81 and when lying 80; and when the exceptions (which were more numerous in proportion than in males) were excluded, the averages were, standing 91, sitting 84, lying 79; the difference between standing and sitting was four 7 beats, or 1-13th of the whole; that between sitting and lying was 4, or 1-21st of the whole; and that between standing and lying was 11 or 1-8th of the whole. In both sexes, the effect produced by *change* of posture increases with the usual frequency of the pulse; whilst the exceptions to the general rule are more numerous, as the pulse is less frequent. The variation is temporarily increased by the muscular effort, involved in the absolute change of the posture; and it is only by the use of a revolving board, by which the position of the body can be altered, without any exertion on the part of the subject of the observation, that correct results can be obtained. That the difference between standing and sitting should be greater than that between sitting and lying, is just what we should expect, when we compare the amount of muscular effort required in the maintenance of the two former positions respectively.

e. The pulse is well known to be much accelerated by *Mental excitement*, especially by that of the Emotions; it is also quicker during *Diges-*

prevalent notion, has been determined by the observations of Leuret and Mitivié ("De la Fréquence des Pouls chez les Aliénés"), Dr Pennock ("Amer. Journ. of Med. Sci., July, 1847), and Prof. Volkmann (Op. cit. p. 427).

* "Guy's Hospital Reports," vol. iii. p. 312; and "Cyclop. of Anat. and Physiol., vol. iv., Art. 'Pulse.'

† With his usual zeal for *formularization*, Volkmann expresses this ratio, as deduced from a large number of observations, by the ratio $p : p' = h'^{\frac{5}{9}} : h^{\frac{5}{9}}$ (p being the rate of the pulse, and h the height of the body); or, in other words, the ratio is that of *the ninth root of the fifth power* of the height. Surely this is riding a hobby to the death.

cations or anastomoses exist among these branches, so that, by continual subdivision and inosculation, their distribution comes more and more to resemble the capillary network in which they terminate (Fig. 6). Although the *diameters* of the branches, at each subdivision, together exceed that of the trunk, yet there is but little difference in their respective *areas*. What difference does exist, however, is usually in favour of the branches; and thus it happens that there is a gradual increase in the capacity of the arterial system from its centre towards the capillaries, whose capacity is many times greater (§ 263).—The Arteries exert a most important influence upon the movement of blood through them, in virtue of the physical and vital properties of their walls, or rather of their middle or fibrous coat, which alone is possessed of contractile properties. We find in this coat a layer of yellow Elastic tissue, which is much thicker in the *larger* arteries, in proportion to their size, than in the smaller. On the inside of this is a layer of annular fibres, composed of Muscular fibre-cells, mingled with areolar tissue;* the muscular element, however, is much more abundant in the *smaller* arteries, than in the larger. To the former tissue is due the simple *elasticity* of the arterial walls, which is a physical property that persists after death, until a serious change takes place in their composition; whilst to the latter we are to attribute the property which they unquestionably possess (in common with proper muscular tissue), of *contracting* on the application of a stimulus, so long as their vitality remains. These two endowments are possessed in various degrees, proportional to the respective predominance of the elastic or of the muscular tissue, by the different parts of the Arterial system. Thus, as was justly remarked by Hunter, the *elasticity*, being the property by which the interrupted force of the Heart is made equable and continuous, is most seen in the large vessels more immediately connected with that organ; whilst on the other hand, the *contractility* is most observable in the smaller vessels, where it is more required for regulating the flow of blood towards particular organs.

256. It has been denied by many Physiologists, that the middle coat of the Arteries possesses any property that can be likened to Muscular *Irritability*, but no reasonable doubt can any longer exist on this point. Although many experimenters have failed in producing contractions of their walls by stimuli directly applied to themselves, yet such contractions may be so easily demonstrated by proper means, that the negative results cannot be admitted as invalidating the fact. It is of course in the smaller arteries, that the evidence of this contractility should be sought; and this may be readily obtained by observing the effects of various stimuli, mechanical, chemical, or electrical, upon the vessels of a transparent membrane, such as the bat's wing or the frog's foot. Thus if, whilst we watch the movement of blood in a companion artery and vein, we draw the point of a fine needle across them three or four times, without apparently injuring them or the membrane over them, they will both presently contract and close; then, after remaining for a few minutes in the contracted state, they will begin again to dilate, and will gradually increase in diameter until they acquire a larger size than before the stimulus was applied. When in this condition, they will not again contract on the

* See Prof. Kolliker's "Manual of Human Histology" (Sydenham Society's Edit.) vol. ii. p. 291.

inferred to exist from the act of blushing and other analogous phenomena, is capable of experimental demonstration. Thus, Valentin and others have succeeded in producing evident contractions in the Aorta, by irritation of the Sympathetic nerve, and of the roots of the cervical nerves of the Spinal system. It is in the smaller arteries, however, that, for reasons already given (§ 255), we should expect to find the best evidence of the excitability of muscular contraction through their nerves. And such evidence has been afforded by the experiments of Dr. Aug. Waller who has shown, that whilst section or ligature of the Sympathetic trunk on either side of the neck produces an enlargement of the minute arteries on that side of the face (as is best seen in the lining of the external ear of the cat or rabbit), accompanied with an elevation of temperature, the application of galvanism to the nerve for a minute or less, causes them to contract to their ordinary calibre.*

258. Several experiments also indicate the existence of that power of slow contraction in the arteries, which has been distinguished by the appellation *Tonicity.* Thus, when a ligature is placed upon an artery in a living animal, the part of the artery beyond the ligature becomes gradually smaller, and is emptied to a certain degree, if not completely, of the blood it contained. Again, when part of an artery in a living animal is isolated by means of two ligatures, and is punctured, the blood issues from the orifice, and the inclosed portion of the artery is almost completely emptied of its contents. Further, every Surgeon knows, that the contraction of divided arteries is an efficient means of the arrest of hæmorrhage from them, especially when they are of small calibre, so that, in the case of the temporal artery for example, the complete division of the tube is often the readiest means of checking the flow of blood from it, when it has been once wounded. This contraction is much greater than could be accounted-for by the simple *elasticity* of the tissue and is more decided in small than in large vessels. The empty condition of the arteries, generally found within a short time after death, seems to be in part due to the same cause, since their calibre is usually much diminished, and is sometimes completely obliterated. A remarkable example of the same slow contraction, is that which takes place in the end of the upper portion of an arterial trunk, when the passage of blood through it is interrupted by a ligature; for the current of blood then passes-off by the nearest large lateral branch; and the tube of the artery shrivels, and soon becomes impervious, from the point at which the ligature is applied, back to the origin of that branch. This last fact is important, as proving how little influence the *vis a tergo* possesses over the calibre of arterial tubes; since, without any interruption to the pressure of blood occasioned by it, the tube becomes impervious. It is to the moderate action of the *tonicity* of arteries, that their contraction upon the stream of blood passing through them (which serves to keep the tubes always full) is due. If the tonicity be excessive, the pulse is hard and wiry; but if it be deficient, the pulse is very compressible, though bounding, and the flow of blood through the arteries is retarded. Dr. C. J. B. Williams has performed some ingenious experiments (§ 280), which prove

* See "Comptes Rendus," 1853, tom. xxxvi. p. 378. Of this remarkable experiment, which first demonstrated the influence of the Sympathetic Nerve upon the smaller arteries, the Author, by the kindness of Dr. Waller, has himself been a witness.

arteries supplying parts that are in a state of active increase, must be due, not to simple dilatation merely, but to augmented nutrition; since we find that their walls are thickened as well as extended. And on the other side, when slow contraction occurs in these tubes, as a consequence of disease, it must be in part occasioned by atrophy; since their nutrition is so much diminished, that in time they almost entirely disappear,—a portion of a large artery shrivelling into a ligamentous band.

260. The purpose served by the *Elasticity* of the Arteries, is one of a purely physical character; its effect being to convert the intermitting impulses, which the blood receives from the heart, into a continuous current. The former are very evident in the larger trunks; but they diminish with the subdivision of these, until they entirely disappear in the capillaries, in which the stream is usually equable or nearly so. If a powerful force-pump were made to inject water, by successive strokes, into a system of tubes with unyielding walls, the flow of fluid at the farther extremities of these tubes would be as much interrupted as its entrance into them. But if an air vessel (like that of a fire-engine) were placed at their commencement, the flow would be in a great degree equalized; since a part of the force of each stroke would be spent upon the compression of the air included in it; and this force would be restored by the elasticity of the air during the interval, which would propel the stream, until directly renewed by the next impulse. A much closer imitation of the natural apparatus would be afforded by a pipe which had elastic walls of its own; thus if water were forced by a syringe into a long tube of caoutchouc, for example, the stream would be equalized before it had proceeded far. This effect is found to be accomplished, at any point of the Arterial circulation, in a degree proportionate to its distance from the Heart; and in this mode it is, that the intermitting force of the ventricular contraction is almost equably distributed over the whole of the interval between one systole and another, by the contraction of the elastic tubes in the dilatation of which it was at first expended.—Another effect of this elasticity is to distribute the pressure of the blood upon the walls of the arteries, much more equally than would be the case if they formed a system of rigid tubes. For, according to Volkmann,* since the lateral pressure of a liquid moving through tubes of uniform calibre with rigid walls, is proportional to the resistance to be overcome at each point, and since this resistance depends upon the adhesion and friction between the liquid and the parietes of the tube, the lateral pressure at each point will vary inversely with the distance of that point from the discharging orifice. Consequently, if the arteries constituted a system of rigid tubes, the pressure on their walls would decrease very rapidly, in passing from the heart towards their peripheral extremities. Such, however, is far from being the case; for although the pressure is by no means equal throughout (§ 263), yet it does not vary in any such ratio.

261. The distension of the Arteries that is consequent upon the intermittent injection of blood into their trunks, and the subsequent contraction which results from the elasticity of their walls, give rise to the *pulsation* which is perceptible to the touch in all but the smallest arteries.

* "Hæmodynamik," p. 38.

condition of rigid tubes, and the pulse at the wrist is almost exactly synchronous with the heart's beat; whilst, if the tonicity be defective, the radial pulse is felt at a long interval after the heart's beat, and the difference is still more perceptible when the pulse is examined in the feet. The longest interval in a state of health seems to be between 1-6th and 1-7th of a second.

262. The *rate of movement* of the blood in the Arteries can only be guessed-at, as regards the Human subject, from the comparative results of experiments upon the lower animals. It is stated by Volkmann (Op. cit., p. 196) that the average velocity of the current in the carotid of a considerable number of Mammals which he examined, was about 300 millim., or nearly 12 inches, per second; that the velocity is greater in the arteries lying near, than in those at a distance from the heart; that it is not increased by an augmentation in the number of pulsations,* but that it is greatly augmented by an increase in the volume of the blood, and lessened by its diminution. It appears from the observations of the Profrs. Weber already referred-to (§ 256), that the velocity undergoes a marked increase in branches of arteries whose diameter has been diminished by the contraction of their walls, the acceleration being proportionate to the narrowing of the tube, as might *à priori* be expected; a gradual retardation took place with the return of the artery to the original diameter; and when, as sometimes happened, the vessel dilated to more than its former dimensions, a positive diminution in the rate of movement in the blood was observable.

263. The *lateral pressure* of the blood against the walls of the arteries was affirmed by Poisseuille to be equal throughout the whole arterial system; but the more accurate experiments of Volkmann (made with Ludwig's 'kymographion,' which is a far more trustworthy instrument than the 'hæmadynamometer' of Poisseuille) have shown that this statement is far from being correct. The pressure of the blood, he remarks, is no constant magnitude, but is incessantly changing according to the stroke of the heart, the movements of respiration, and the muscular actions of the body generally. A gradual diminution of its amount, however, may be nearly constantly traced from the commencement of the arterial to the termination of the venous system; and this is to be partly accounted for by the increase in the calibre of the vascular system which takes place as we pass from the arterial trunks to their ramifications (§ 255), and still more from the arterial to the venous system (§ 277); and partly by the diminution of resistance (which is the essential cause of the lateral pressure) as the blood moves-onwards towards its point of discharge (§ 260). The following table presents the results

actually synchronous with the heart's beat, was really dependent upon the preceding ventricular systole, the whole of the interval between one systole and another being required for the transmission of the pulse-wave from the heart to the wrist, as was proved by tracing it from the centre towards the periphery of the arterial system. Now in this case, if the marked want of synchronism between the pulse at the wrist and in the neck had not excited attention, the synchronism between the radial pulse and the heart's beat would have passed as an ordinary occurrence, instead of being a very extraordinary phenomenon.

* On this very important point, the observations of Volkmann are in full accordance with the results of some of Hering's experiments performed with special reference to it (§ 252).

it is returned by the radicles of the veins on the other. The walls of the tubes are composed of a delicate membrane, in which an appearance of transverse striation (as if produced by minute annular fibres) can sometimes be discerned; they contain nothing, however, that is in the least degree comparable to any form of muscular fibre. Bodies having the appearance of cell nuclei may frequently be seen in the walls of the capillaries of embryos and of tadpoles; and these are too wide apart to warrant the idea, that they are the nuclei of epithelial cells, such as those which line the larger vessels. Similar nuclei may be brought into view in the capillaries of adult animals, by treating them with acetic acid; and they are particularly well seen in the Pia Mater, which consists almost entirely of a congeries of blood-vessels (Fig. 42.) The accompany-

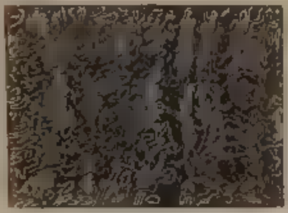
Fig. 42.

Capillary Blood-vessels from Pia Mater; *a*, calibre of the tube, partly occupied by oval nuclei, alternately arranged lengthways and epithelial in their character; *b*, *b*, *b*, nuclei projecting on the exterior of the tube; *c*, *c*, walls, and *d*, calibre, of a large branch; *f*, *f*, oval nuclei, arranged transversely. Magnified 410 diameters.

ing figure shows the contrast between the long oval nuclei *b*, *b*, imbedded at intervals in the walls of the true capillaries, and rather projecting on their exterior; and the nuclei of the epithelium-cells, *f*, *f*, lining the interior of a larger branch, which last are more numerous and of less regular form, and are sometimes placed transversely to the direction of the tube. The diameter of the Capillaries varies in different animals, in accordance with that of their blood-corpuscles; thus the Capillaries of the Frog are, of course, much larger than those of Man. The ordinary diameter of the latter appears, from the measurements of Weber, Muller, and others, to vary from about the 1-3700th to the 1-2500th of an inch; the extremes, however, are stated by Kolliker at as little as 1-5600th and as much as 1-1870th of an inch. As the diameter of the Human capillaries, however, can only be examined after death, it is probable that

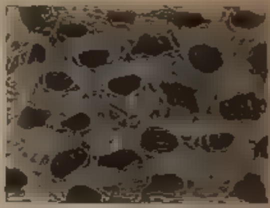
tion than is seen in the generality of the last-named parts, in virtue of the peculiar activity of the molecular changes which take place in them.

Fig. 43.



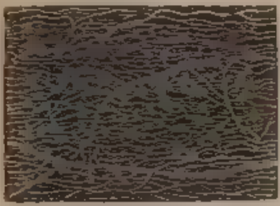
Distribution of *Capillaries* on the surface of the *Skin* of the finger.

Fig. 44.



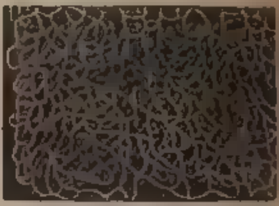
Distribution of *Capillaries* around follicles of *Mucous Membrane*.

Fig. 45.



Distribution of *Capillaries* in *Muscle*.

Fig. 46.



Capillary net-work around Fat-cells.

But the arrangement of vessels peculiar to each, evidently has reference only to the convenience of the distribution of blood among the elementary parts of the tissue, and varies with their form. It is not possible to imagine that it has any other relation than this to their function; since the function of each separate element of the organ, of which that of the entire organ is the aggregate, is due to its own inherent vital powers, the supply of blood being only required, as furnishing the material on which these are to be exercised.

266. The average *rate of movement* of the blood through the capillary system, may be determined with tolerable precision by microscopic measurement; and the observations of Hales, Valentin, and Weber concur in representing it to be from 1 inch to 1½ inch per minute in the systemic capillaries of the Frog; 1·2 inch per minute, or ·02 inch per second, being about the average. In warm-blooded animals, however, the capillary circulation is probably much more rapid than this; the observations of Volkmann upon the mesenteric arteries of the Dog make its rate about ·03 inch per second, or 1·8 inch per minute; and it seems reasonable to suppose that the exposure of the membrane to the cool air would produce a considerable reduction in the normal rapidity of the flow of blood through it. Assuming ·03 inch per second, however, as the rate, and comparing this with the rate of movement of the blood in the larger arteries, which seems on the average to be 11·8 inches per second, it is calculated by Volkmann that the aggregate area of the capillaries (being in an inverse ratio to the rate of the blood's movement through them)

even to the entire reversal, for a time, of the direction of the movement in certain of the transverse or communicating branches, the flow always taking place, of course, from the stronger towards the weaker current. Not unfrequently, an entire stagnation of the current in some part of a tube, precedes this reversal of its direction. Irregularities of this kind, however, are more frequent when the Heart's action is partly interrupted; as it usually is by the pressure to which the tadpole or other animal must be subjected, in order to allow microscopic observations to be made upon its circulation. Under such circumstances, the varieties in the capillary circulation, induced by causes purely local, become very conspicuous; for when the whole current is nearly stagnated, and a fresh impulse from the heart renews it, the movement is not by any means uniform (as it might have been expected to be) through the whole plexus supplied by one arterial trunk, but is much greater in some of the tubes than it is in others; the variation being in no degree connected with their size, and being very different at short intervals.

269. The movement of the blood in the Capillaries of cold-blooded animals, after complete excision of the Heart, has been repeatedly witnessed. In warm-blooded animals, this cannot be satisfactorily established by experiment, since the shock occasioned by so severe an operation much sooner destroys the general vitality of the system; but it may be proved in other ways to take place. After most kinds of natural death, the arterial system is found, subsequently to the lapse of a few hours, almost or completely emptied of blood; this is partly no doubt, the effect of the tonic contraction of the tubes themselves, but the emptying is commonly more complete than could be thus accounted for, and must therefore be partly due to the continuance of the capillary circulation. It has been observed by Dr. Bennet Dowler,* that in the bodies of individuals who have died from yellow fever, the external veins frequently become so distended with blood *within a few minutes* after the cessation of the heart's action, that, when they are opened, the blood flows in a good stream, being sometimes projected to the distance of a foot or more, especially when pressure is applied above the puncture, as in ordinary blood-letting. It is not conceivable that the slowly acting tonicity of the arteries should have produced such a result as this; which can scarcely, therefore, be attributed to anything else than the sustenance of the capillary circulation by forces generated within itself. Further, it has been well ascertained that a real process of secretion not unfrequently continues after general or somatic death; urine has been poured-out by the ureters, sweat exuded from the skin, and other peculiar secretions formed by their glands; and these changes could scarcely have taken place, unless the capillary circulation were still continuing. In the early embryonic condition of the highest animals, the movement of blood seems to be unquestionably due to some diffused power, independent of any central impulsion, for it may be seen to commence in the Vascular Area, before it is subjected to the influence of the Heart. The first movement is *towards*, instead of *from*, the centre; and even for some time after the circulation has been fairly established, the walls of the Heart

* "Researches, Critical and Experimental, on the Capillary Circulation," reprinted from the "New Orleans Medical and Surgical Journal," Jan 1849

although it might be urged, that this increased determination may not be the effect, but the cause, of the increased local action, such an opinion could not be sustained without many inconsistencies with positive facts. For it is known that such local determinations may take place, not only as a part of the regular phenomena of growth and development (as in the case of the entire genital system at the time of puberty and of periodical heat, the uterus after conception, and the mammæ after parturition) but also as a consequence of a strictly local cause. Thus, the student is well aware that, after several hours' close application, there is commonly an increased determination of blood to the brain, causing a sense of oppression, a feeling of heat, and frequently a diminished action in other parts; and, again, when the capillary circulation is being examined under the microscope, it is seen to be quickened by moderate stimuli, and to be equally retarded by depressing agents. All these facts harmonise completely with the phenomena, which are yet more striking in the lower classes of organized beings, and which are evidently in accordance with the same laws.

272. It is equally capable of proof, on the other hand, that an influence generated in the Capillaries may afford a complete check to the circulation in the part; even when the Heart's action is unimpaired, and no mechanical impediment exists to the transmission of blood. Thus, cases of spontaneous Gangrene of the lower extremities are of no unfrequent occurrence, in which the death of the solid tissues is clearly connected with a local decline of the circulation; and in which it has been shown by examination of the limb after its removal, that both the larger tubes and the capillaries were completely pervious; so that the cessation of the flow of blood could not be attributed to any impediment, except that arising from the cessation of some power which exists in the capillaries and which is necessary for the maintenance of the current through them. The influence of the prolonged application of Cold to a part, may be quoted in support of the same general proposition; for, although the calibre of the vessels may be diminished by this agent, yet their contraction is not sufficient to account for that complete cessation of the flow of blood through them, which is well known to occur, and to terminate in the loss of their vitality. The most remarkable evidence on this point, however, is derived from the phenomena of Asphyxia, which will be more fully explained in the succeeding Chapter (§§ 326, 327). At present it may be stated as a fact, which has now been very satisfactorily ascertained, that, if admission of air into the lungs be prevented, the circulation through them will be brought to a stand, as soon as the air which they contain has been to a great degree deprived of its oxygen, or rather has become loaded with carbonic acid; and this stagnation will, of course be communicated to all the rest of the system. Yet, if it have not continued sufficiently long to cause the loss of vitality in the nervous centres, the movement may be renewed by the admission of air into the lungs. Now although it has been asserted, that the stagnation is due to a mechanical impediment, resulting from the contracted state of the lungs in such cases, this has been clearly proved not to be the fact, by causing animals to breathe a gas destitute of oxygen, so as to produce Asphyxia in a different manner; for the same stagnation results, as in the other case.

tions in the chemical state of the blood (involving, of course, important changes in its vital properties) are capable of exercising a most important effect on the Capillary circulation, is shown, not merely by the stagnation of the *pulmonary* Circulation in Asphyxia (§ 327), but by the curious fact ascertained by Dr. J. Reid,* that the blood, when imperfectly arterialised, is retarded in the *systemic* capillaries, causing an increased pressure on the walls of the arteries. He found that, when the ingress of air through the trachea of a Dog was prevented, and the Asphyxia was proceeding to the stage of insensibility,—the attempts at inspiration being few and laboured, and the blood in an exposed artery being quite venous in its character,—the pressure upon the arterial walls, as indicated by the hæmadynamometer applied to the femoral artery, was much greater than usual. Upon applying a similar test to a vein, however, it was found that the pressure was proportionably diminished; whence it became apparent, that there was an unusual obstruction to the passage of venous blood through the systemic capillaries. After this period, however, the mercury in the hæmadynamometer applied to the artery began to fall steadily, and at last rapidly, in consequence of the diminished force of the heart, and the retardation of the blood in the pulmonic capillaries; but, if atmospheric air was admitted, the mercury rose *instantly*, showing that the renewal of the proper chemical state of the blood restored the condition necessary for its circulation through the capillaries.†

275. It appears from the preceding facts, that the conditions under which the power in question uniformly operates, may be thus simply and definitely expressed: Whilst the injection of blood *into* the Capillary vessels of every part of the system, is due to the action of the Heart, its rate of passage *through* those vessels is greatly modified by the degree of activity in the processes, to which it should normally be subservient in them; the current being rendered more rapid by an increase in their activity, and being stagnated by their depression or total cessation. Or at any rate, to use the more guarded language of Mr. Paget (loc. cit.), we have facts enough to justify the hypothesis, "that there is some mutual relation between the blood and its vessels, or the parts around them, which, being natural, permits the most easy transit of the blood, but, being disturbed, increases the hindrances to its passage."—A physical principle has been put-forth by Prof. Draper,‡ which seems quite adequate to explain these phenomena. It appears fully capable of proof, that "if two liquids communicate with one another in a capillary tube, or in a porous or parenchymatous structure, and have for that tube or structure different chemical affinities, movement will ensue; that liquid which has the most energetic affinity will move with the greatest velocity, and may even drive the other liquid before it." Now Arterial blood,—containing oxygen with which it is ready to part, and being

* "Edinb. Med. and Surg. Journ.," April, 1841; and "Anat., Phys., and Pathol. Researches," chap. ii.

† This last fact (as Dr. Reid has remarked) is sufficient to negative the idea of Mr. Erichsen, that the obstruction is caused by the *contraction of the capillaries* under the stimulus of venous blood ("Edinb. Med. and Surg. Journ.," Jan. 1845), for all experiments agree in showing, that such contraction can only be excited by the application of a stimulus for some minutes, and that relaxation takes place still more slowly (§ 256).

‡ "Treatise on the Forces which produce the Organization of Plants," pp. 22–41.

flow without any apparent alteration, after section of the nerves of the part, as has been observed by Muller, Wharton Jones, and others and this corresponds with the well-known fact, that the Nutritive and Secretory processes may take place, after Nervous agency has been [illegible] suspended. But it seems indubitable that a sudden and violent 'shock' to the Nervous centres may exert the same antagonistic influence on the movement of blood in the Capillaries, as we have seen it to do on the Heart's action (§ 238). for this appears alike from the immediate and total annihilation of all vital activity which is consequent upon such an injury, and from direct observation in such an experiment as the following, made by Dr. Wilson Philip. "The web of one of the hind legs of a frog was brought before the microscope; and while Dr Hastings observed the circulation, which was vigorous, the brain was crushed by the blow of a hammer. The vessels of the web *instantly* lost their power, the circulation ceasing; an effect which cannot arise, as we have seen, from the ceasing of the action of the heart. [Dr. P. here refers to experiments, by which it was ascertained, that the circulation in the capillary vessels of the frog will continue for several minutes, after the interruption of the heart's action.] In a short time the blood again began to move, but with less force. This experiment was repeated, with the same result. If the brain is not completely crushed, although the animal is killed, the blow, instead of destroying the circulation, increases its rapidity."*

5.—*Movement of the Blood in the Veins.*

277. The Venous system takes its origin in the small trunks that are formed by the re-union of the Capillaries; and it returns the blood from these to the Heart. The structure of the Veins is essentially the same with that of the Arteries; but the fibrous tissue of which their middle coat is made-up, bears more resemblance to the areolar tissue of the skin, than it does to the true elastic tissue, and the muscular fibre-cells are usually much fewer in number, and are sometimes wanting altogether.† The *elasticity* of the Veins is shown by the jet of blood which at first spouts-out in ordinary venesection, when, by means of the ligature, a distension has been occasioned in the tubes below it. A slight *contractility* on the application of stimuli, and on irritation of the Sympathetic nervous fibres, has been observed; but this is not so decided as in the arteries. The whole capacity of the Venous system is considerably greater than that of the arterial; the former is usually estimated to contain from 2 to 3 times as much blood as the latter, in the ordinary condition of the circulation; and when we consider the great proportion which the Veins in almost every part of the body bear to the arteries, we shall scarcely regard even the larger of these ratios as exaggerated. Of course the rapidity of the movement of the blood in the two systems will bear an inverse ratio to their respective capacities; thus if, in [illegible]

* "Experimental Inquiry into the Laws of the Vital Functions," 4th edition, p. [illegible]

† The following, according to Prof. Kolliker ("Manual of Human Histology", Syd. Soc. vol. ii. p. 307,) are Veins which are unprovided with muscular structure:— The veins of the uterine portion of the placenta, the veins of the cerebral substance and pia mater, the sinuses of the dura mater, Breschet's veins of the bones, the venous spaces of the corpora cavernosa in the male and female, and probably the venous cells of the spleen.

On the other hand, the *expiratory* movement, while it directly causes accumulation in the veins, will assist the heart in propelling the blood into the arteries; and by the combined action of these two causes is produced among other effects, the rising and sinking of the Brain, synchronously with expiration and inspiration, which are observed when a portion of the cranium is removed. Several considerations, however, agree in pointing to the conclusion, that no great efficacy can be rightly attributed to the Respiratory movements, as exerting any *general* influence over the Venous circulation. The Pulmonary circulation, being entirely within the chest, cannot be affected by variations in atmospheric pressure; the entire venous circulation of the fœtus, also, is independent of any such agency. Again, it has been shown experimentally by Dr. Arnott and others, that no suction-power exerted at the farther end of a long tube whose walls are so deficient in firmness as are those of the Veins, can occasion any acceleration in a current of fluid transmitted through it; for the effect of the suction is destroyed, at no great distance from the point at which it is applied, by the flapping-together of the sides of the vessels.

279. One of the most powerful of the general causes which influence the Venous circulation, is doubtless the frequently-recurring *pressure of the muscles* upon their trunks. In every instance that Muscular movement takes place, a portion of the Veins of the part will undergo compression; and as the blood is prevented, by the valves in the veins, from being driven-back into the small vessels, it is necessarily forced-on towards the heart. As each set of muscles is relaxed, the veins compressed by it fill-out again, to be again compressed by the renewal of the force. That the general Muscular movement is an important agent in maintaining the circulation, at a point above that at which it would be kept by the action of the heart and arterial system alone, appears from several considerations. The pulsations are diminished in frequency by rest, accelerated by exertion, and very much quickened by violent effort (§ 254 *d*). In all kinds of exercise, and in almost every sort of effort, there is that alternate contraction and relaxation of particular groups of Muscles, which has been just mentioned as affecting the flow of blood through the veins; and there can be little doubt, that the increased rapidity of the return of blood through them, is of itself sufficient cause for the accelerated movements of the heart. When a large number of muscles are put in action after repose, as is the case when we rise-up from a recumbent or a sitting posture, the blood is driven to the heart with a very strong impetus; and if that organ should be diseased, it may arrive there in a quantity larger than can be disposed-of, so that sudden death may be the result. Hence the necessity for the avoidance of all sudden and violent movements, on the part of those who labour under either a functional or a structural disease of the centre of the circulation.

280. The Venous circulation is much more liable than the Arterial to be influenced by the force of Gravity; and this influence is particularly noticeable, when the tonicity of the vessels is deficient.—The following experiments performed by Dr. C. J. B. Williams,* to elucidate the influence of deficient firmness in the walls of the vessels, and of gravitation

* "Principles of Medicine," 2nd edit., p. 188.

circulation; the chief peculiarity of which is, that *venous* blood is sent *from* the heart, through a tube which is arterial in its structure, whilst *arterial* blood is returned *to* the heart, through a vessel whose structural character is that of a vein. The movement of the blood through these is considerably affected by the physical state of the lungs themselves; being retarded by any causes, which can occasion pressure on the vessels (such as over-distension of the cells with air, obstruction of their cavity by solid or fluid depositions, or by foreign substances injected into them, &c.) and proceeding with the greatest energy and regularity, when the respiratory movements are freely performed. —The *Portal* circulation, again, is peculiar, in being a kind of offset from the general or systemic circulation; and also in being destitute of valves; and it may be surmised with much probability, that the purpose of their absence is, to allow of an unusually free passage of blood from one part of that system to another, during the very varying conditions to which it is subjected (§ 151).—Another very important modification of the Circulating system, is that which presents itself within the *Cranium*. From the circumstance of the cranium being a closed cavity, which must be always filled with the same total amount of contents, the flow of blood through its vessels is attended with some peculiarities. The pressure of the atmosphere is here exerted, rather to keep the blood in the head, than to force it out; and it might accordingly be inferred, that, whilst the quantity of cerebral matter remains the same, the amount of blood in the cranial vessels must also be invariable. This inference appeared to derive support from the experiments of Dr Kellie. On bleeding animals to death, he found that, whilst the remainder of the body was completely exsanguine, the usual quantity of blood remained in the arteries and veins of the cranium; but that if an opening was made in the skull, these vessels were then as completely emptied as the rest. It is not to be hence inferred, however, that the absolute quantity of blood within the cranium is not subject to variation; and that in the states of inflammation, congestion, or other morbid affections, there is only a disturbance of the usual balance of the arterial and venous circulation. The fact in all probability is rather, that the softness of the Cerebral tissue, and its varying functional activity, render it peculiarly liable to undergo alterations in bulk; and that the amount of the 'cerebro-spinal fluid' varies considerably at different times; so that the quantity of blood may thus, even in the healthy condition, be continually changing. Moreover in disordered states of the circulation, the quantity of blood in the vessels of the cranium may be for a time diminished by a sudden extravasation either of blood or serum, into the cerebral substance; and the amount of interior *pressure* upon the walls of the vessels may also be considerably altered, even when there is no difference in the *quantity* of fluid contained in them.†

282. The *Erectile Tissues* present another curious modification of the ordinary vascular apparatus. The chief of these are the corpora cavernosa in the penis of the male, and in the clitoris of the female; the collection of similar tissues round the vagina, and in the nymphæ, of the female; and the nipple in both sexes. In all these situations, erection may be

* "Edinburgh Medico-Chirurgical Transactions," vol. i.

† The results of the more recent experiments of Dr G. Burrows ("Medical Gazette," April and May, 1843) fully confirm the views stated above.

CHAPTER VII.

OF RESPIRATION.

1.—*Nature of the Function: and Provisions for its Performance*

283. The Nutritive fluid, in its circulation through the capillaries of the system, undergoes great alterations both in its physical constitution, and in its vital properties. It gives up to the tissues with which it is brought into contact, some of its most important elements; and, at the same time, it is made the vehicle of the removal, from these tissues, of ingredients which are no longer in the state of combination that fits them for their offices in the Animal Economy. To separate these ingredients from the general current of the circulation, and to carry them out of the system, is the great object of the Excretory organs; the importance of whose respective functions will vary, it is very evident, with the amount of the ingredient which they have to separate, and with the deleterious influence which its retention would exert on the welfare of the system at large. Of all these injurious ingredients, Carbonic Acid is without doubt the one most abundantly introduced into the nutritive fluid; and it is also most deleterious in its effects on the system, if allowed to accumulate.—We find, accordingly, that the provision for the removal of this substance from the blood, is one of peculiar extent and importance, especially in the higher forms of animals; and further, that instead of being effected by an operation peculiarly *vital* (like other acts of Excretion), its performance is secured by being made to depend upon simple *physical* conditions, and is thus comparatively little susceptible of derangement from disorder of other processes. All that is requisite for it, is the exposure of the Blood to the influence of the Atmospheric air (or, in aquatic animals, of air dissolved in water), through the medium of a membrane that shall permit the 'diffusion of gases;' an interchange then taking place between the gaseous matters on the two sides,—Carbonic acid being exhaled from the Blood, and being replaced by Oxygen from the air. Thus the extrication of Carbonic acid is effected in a manner that renders it subservient to the introduction of that element which is required for all the most active manifestations of vital power; and it is in these two processes conjointly, not in either alone, that the function of Respiration essentially consists.—We shall now inquire into the sources from which Carbonic acid is produced in the living body, and the causes of the demand for Oxygen.

284. The vital activity of the organism at large involves a continual change in its constituent parts; and those which (so to speak) live the fastest, usually die the soonest, and pass most readily into decay (CHAP. VIII., Sect. 1). Hence in the very performance of the Organic functions which concur to effect the Nutrition of the body, there is a constant source of disintegration; and one of the chief products of the decay of the tissues, which is consequent upon their loss of vitality, is Carbonic acid.—Thus the *most general* object of the Respiratory process, which is

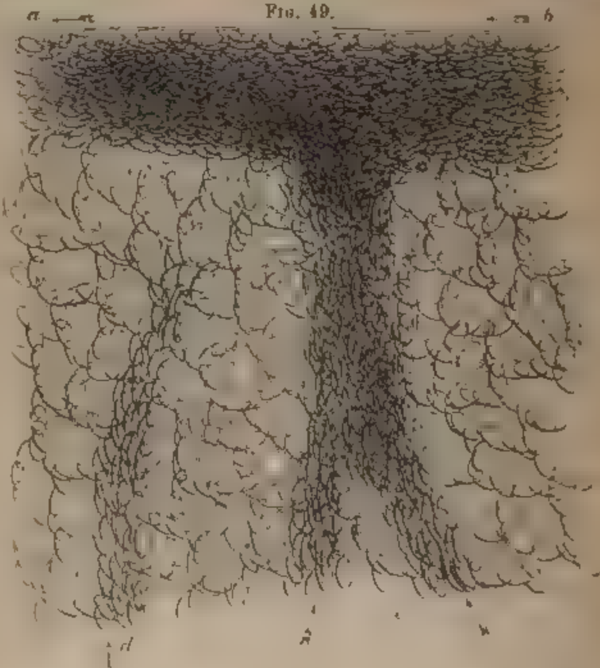
tegrating tissues, the metamorphosis of which takes place at a very rapid rate; but where this is not sufficient, their power of maintaining to a temperature depends upon the *direct* combination of certain elements of the food with the oxygen of the air, by the combustive process.—The quantity of carbonic acid that is generated directly from the elements of the food, seems to vary considerably in different animals, and in different states of the same individual. In the Carnivorous tribes, which spend the greater part of their time in a state of activity, it is probable that the quantity which is generated by the waste or metamorphosis of the tissues is sufficient for the maintenance of the required temperature; and that little or none of the carbonic acid set-free in respiration, is derived from the direct combustion of the materials of the food. But in Herbivorous animals of comparatively inert habits, the amount of metamorphosis of the tissues is far from being sufficient, and a large part of the food, consisting as it does of substances that cannot be applied to the nutrition of the tissues, is made to enter into direct combination with the oxygen of the air, and thus to compensate for the deficiency. In Man and other animals, which can sustain considerable variations of climate, and can adapt themselves to a great diversity of habits, the quantity of carbonic acid formed by the direct combination of the elements of the food with the oxygen of the air, will differ extremely under different circumstances (§ 55). It will serve as the *complement* of that which is formed in other ways; so that it will diminish with the increase, and will increase with the diminution, of muscular activity. It will also vary in an inverse ratio to the external temperature, increasing with its diminution (as more heat must then be generated), and diminishing with its increase; the effect of external heat being thus precisely opposite, in the warm-blooded animal, to that which it exerts on the cold blooded (§ 284).—In all cases, if a sufficient supply of food be not furnished, the store of fat is drawn-upon; and if this be exhausted, the animal dies of cold (§ 70).

287. To recapitulate, then, the sources of Carbonic Acid in the animal body are threefold.—I. The continual decay of the tissues common to all organized bodies, which is favoured by whatever promotes their vital activity, and is retarded by every influence that depresses it.—II. The metamorphosis peculiar to the Nervous and Muscular tissues, which is the very condition of the production of their power, and which therefore bears a direct relation to the degree in which they are exerted.—III. The direct conversion of the carbon and hydrogen of the food into carbonic acid and water, which is peculiar to warm-blooded animals, and which varies in quantity, in accordance with the amount of heat to be generated.

288. The wonderful nature of the structural arrangements which are made for the aeration of the blood in Man (as in Mammalia generally), and the completeness of the provisions whereby these are put into active operation, will be best understood, if, for the sake of contrast, we first bestow a brief survey on the Pulmonary apparatus of Reptiles; a class in which the demand for respiration is reduced to a comparatively low grade, by the absence of any necessity for the maintenance of an independent temperature, by the general torpor of their habits (whence arises a very small amount of 'waste' in their nervo-muscular apparatus), and by the very slow rate at which their organic functions are performed and

thoracic cavity, and capable, by its contraction, of largely increasing the capacity of that cavity. In fact, many Reptiles are incapable of *drawing* in air, and can only *force* it in by a process resembling deglutition.*

Fig. 49.



Portion of the Lung of a living *Triton*, as seen with the power of 150 diameters.—*a*, *b*, pulmonary vein, receiving blood from the large trunk *c*, and a smaller vessel *d*.

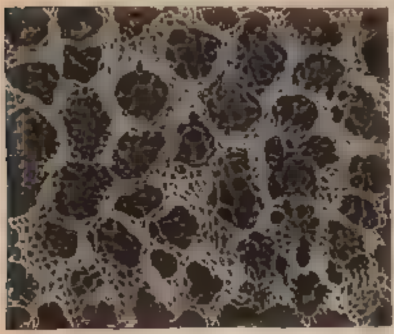
289. The size of the Lungs in Man and the Mammalia is far smaller in proportion to their bulk, than it is in most Reptiles; but this diminution is more than compensated by the minute subdivision of their cavities, by the peculiarity of the distribution of their blood-vessels, and by the arrangements whereby a continual and rapid interchange, both of the blood and of the air, is provided-for.—The following are the points of most importance in the structure of the Human Lung.† The walls of the bronchial tubes contain distinct longitudinal and circular layers of fibrous structure; but the latter alone, according to Prof. Kolliker, contain muscular fibre-cells. These tubes divide and subdivide, like the branches of a tree, still retaining their ordinary characters, until they are no more than from 1-50th to 1-30th of an inch in diameter; and at these the longitudinal and annular fibres, together with the ciliated epithelium, come to an abrupt termination. Beyond this boundary

* For an account of the principal forms of Respiratory apparatus among the lower Animals, see "PRINC. OF COMP. PHYS.," Chap. vi.

† See especially the Memoir by Mr. Rainey in the "Med. Chirurg. Trans.," vol. xxxv.; and Prof. Kolliker's "Manual of Human Histology" (Sydenham Society), vol. ii. pp. 168-178.

quantity.—The diameter of the Human air-cells is about twenty times greater than that of the capillaries which are distributed upon their parietes; varying (according to the measurement of Weber) from the 1-200th to the 1-70th of an inch.* It has been calculated by M. Rochoux, that as many as 17,790 air-cells are grouped around each terminal bronchus; and that their total number amounts to no less than 600 *millions*. The capillary plexus (Fig. 51) is so disposed between the two layers which form the walls of two adjacent air-cells, as to expose one of its surfaces to each; by which provision the full influence of the air upon it is secured. The network of vessels is so close, that the diameter of the meshes is scarcely so great as that of the capillaries which enclose them; indeed it would be impossible to conceive of a method, by which blood, whilst still retained within vessels, should be spread over a larger surface for aeration. And if not restricted within vessels, it could not be ceaselessly and rapidly driven-on by the propulsive power of the heart, which acts no less efficiently upon the pulmonary circulation than upon the systemic, although the force exerted is much inferior, the resisting power being far less, in consequence of the shortness of the circuit.

Fig. 51.



Arrangement of the Capillaries of the air-cells of the *Human Lung*.

291 The fibrous coat of the bronchial tubes possesses a considerable amount of muscular contractility, which (according to the experiments of Dr. C. J. B. Williams†) may be excited by electrical, chemical, or mechanical stimuli, applied to themselves; but this is not so readily excitable through their nerves, although the experiments of Volkmann‡ and Longet§ have clearly shown the possibility of thus calling it into action. This contractility resembles that of the intestines or arteries, more than that of the voluntary muscles or heart; the contraction and relaxation being more gradual than that of the latter, though less tardy than that of the former. It is chiefly manifested in the smaller bronchial tubes, those of less than a line in diameter having been seen to contract gradually under the stimulus of galvanism, until their cavity was nearly obliterated; on the other hand, in the trachea and the larger bronchi, the cartilaginous rings prevent any decided diminution in the calibre of the tubes, and the muscular structure is much less distinct. It is remarked by Dr. Williams, that the contractility of the bronchial

* The dimensions given by Moleschott ("De Vesiculis Pulmonum Malpighianis") are very much less than these, the range of diameter being stated by him at between 1-120th and 1-1200th of an inch. The Author's own observations, however, lead him to regard Weber's statement as very near the truth; and that of Prof. Kolliker is almost precisely the same.

† "Report of the British Association for 1840," p. 411.

‡ "Wagner's Handworterbuch," band ii., Art. 'Nervenphysiologie,' 586.

§ "Anat. et Physiol. du Systeme Nerveux," tom. ii. p. 289.

that when this is enlarged, a vacuum would be produced, if it were not occupied by a corresponding enlargement of the lung; and to effect this, the air rushes down the trachea, and thence passes into the entire substance of the lung, which it fills-out in every dimension. This distension is much more complete than any that could be occasioned by simple insufflation from the trachea; for long before the internal pressure could overcome the resistance set-up by the elasticity of the lungs, and still more by that of the parietes of the chest (§ 295), to the full dilatation of the air-vesicles, the tissue of the lung itself would be almost certain to give way. This has actually happened in numerous instances; and it constitutes a very forcible objection to the use of any apparatus for artificial respiration, whose action is that of 'insufflation.'

293. The complete dependence of the expansion of the Lungs upon the enlargement of the cavity of the chest, is well shown by the effect of admission of air into the pleural cavity. When an aperture is made on either side, so that the air rushes-in at each inspiratory movement, the expansion of the lung on that side is diminished, or entirely prevented, in proportion to the size of the aperture. If air can enter through it more readily than through the trachea, an entire collapse of the lung takes place; and by making such an aperture on each side, complete asphyxia is produced. But if it be too small to admit the very ready passage of air, the vacuum produced by the inspiratory movement is more easily filled by the distension of the lungs, than by the rush of air into the pleural cavity, so that a sufficient amount of change takes place for the maintenance of life. This is frequently observed in the case of penetrating wounds of the thorax, in the surgical treatment of which, it is of great importance to close the aperture as completely as possible; when this has been accomplished, the air that had found its way into the cavity is soon absorbed, and the lung resumes its full play. Where one lung is obstructed by tubercular deposit, or is prevented in any other way from rightly discharging its function, an opening that freely admits air into the pleural cavity of the other side, is necessarily attended with an immediately-fatal result; and in this manner it not unfrequently happens that chronic pulmonary diseases suddenly terminate in Asphyxia, a communication being opened by ulceration between a bronchial tube and the cavity of the thorax.

294. *Of the Respiratory Movements.*—The dilatation of the Pleural cavity during Inspiration, is chiefly accomplished by the contraction of the Diaphragm, which, from the high arch that it previously formed, becomes nearly plane; in this change of figure, it presses on the abdominal viscera, so as to cause them to protrude, which they are enabled to do by the relaxation of the abdominal muscles. In ordinary tranquil breathing (especially in children), the action of the diaphragm is alone nearly sufficient to produce the necessary exchange of air; but, when a full inspiration is required, the cavity of the chest is dilated laterally and antero-posteriorly, as well as inferiorly. The enlargement of the chest in both these directions is effected by the elevation of the ribs; for whilst, in the undilated state of the thorax, the ribs form an angle with their cartilages, which becomes less and less obtuse as we pass from the first rib downwards, the elevation of the ribs tends to bring them and their cartilages more nearly into a line, and thus separates them more widely

the lungs themselves at that degree of distension, making altogether 580 lbs.; and as the subject of this observation could expire during life considerably more air than the highest amount forced into his chest after death, there can be little doubt (judging from the rapid ratio in which the elastic force increases when the distension is approaching its limit) that the muscular power required to overcome this, towards the close of a very deep inspiration, could not have been less than 1000 lbs. The co-operation of the elastic resistance with the expiratory movement, and its antagonism to the inspiratory, is doubtless the principal cause why the power of the expiratory muscles, as tested by the height of the column of mercury supported by the air, should always be greater than that of the inspiratory muscles (see Dr. Hutchinson, Op. cit. p. 1061), and why the expiratory power should be very much greater when the chest has been well filled with air, than when it is comparatively empty. The following is given by Dr. Hutchinson as the range through which these powers may vary within the limits of health:—

Power of Inspiratory Muscles		*Power of Expiratory Muscles*
1·5 inch.	Weak	2·0 inches.
2·0 ,,	Ordinary	2·5 ,,
2·5 ,,	Strong	3·5 ,,
3·5 ,,	Very strong	4·5 ,,
4·5 ,,	Remarkable	5·8 ,,
5·5 ,,	Very remarkable	7·0 ,,
6·0 ,,	Extraordinary	8·5 ,,
7·0 ,,	Very extraordinary	10·0 ,,

The expiratory power may be augmented by the habitual performance of movements in which they participate; and thus the inspiratory power is the preferable test of the *vis vitæ*. This has been found by Dr. Hutchinson to bear some relation to height, being greatest (on an average of a considerable number of cases) when the stature is 5 feet 7 or 8 inches, and diminishing above that height, as well as below it.

296. It is impossible to form a correct estimate, by observations on one's-self, of the usual Number and extent of the respiratory movements; since the direction of the attention to them is certain to increase their frequency and amount. In general it may be stated, that from 16 to 20 alternations usually occur in a minute;* of these, the ordinary inspirations involve but little movement of the thorax; but a greater exertion is made at about every fifth recurrence. The average numerical proportion of the respiratory movements to the pulsations of the heart, is about 1:5, 1:4½, or 1:4; and when this proportion is widely departed from, there is reason to suspect some obstruction to the aeration of the blood, or some disorder of the nervous system. Thus in Pneumonia, in which a greater or less amount of the lung is unfit for its office, the number of respirations increases in a more rapid proportion than the acceleration of the pulse; so that the ratio becomes as 1 to 3, or even 1 to 2, in accordance with the degree of engorgement.† In Hysterical patients, how-

* See Dr. Hutchinson's Table, in "Cyclop. of Anat. and Phys.," vol. iv, p. 1085.

† See a Paper by Dr. Hooker, on the 'Relation between the Respiratory and Circulating Functions,' in the "Boston (N. E.) Medical and Surgical Journal," an abstract of which will be found in the "British and Foreign Medical Review," vol. iv. p. 263.

299. The chief 'excitor' of the respiratory movements is unquestionably the Pneumogastric nerve. When this is divided on both sides, according to the experiments of Dr. J. Reid,* the number of respiratory movements is considerably diminished, usually by about one-half. Now if this nerve excites the motions of respiration by its powerful action in producing *sensation*, we should expect to find its trunk endowed with considerable sensibility, which is not the case; for all experimenters agree in stating, that, when its trunk is pinched or pricked, the animal does not exhibit signs of pain nearly so acute, as when the trunks of the ordinary spinal nerves, or of the fifth pair, are subjected to similar treatment. It cannot be questioned, however, that its power as an excitor of respiration is very great; since, besides the fact of the diminution in the number of inspirations which occurs immediately on section of it, irritation of its trunk in the neck is instantly followed by an act of inspiration. It is evident that this power must arise from *impressions* made upon its peripheral extremities. The impression is probably due to the presence of venous blood in the capillaries of the lungs; or, as Dr. M. Hall thinks, to the presence of carbonic acid in the air-cells. Either or both may be true.—The Pneumogastric nerve, however, is not the only 'excitor' of the respiratory movements; since, when the nerve is cut on each side, these still continue, though with diminished frequency. The removal of the Encephalon lessens the frequency of the respiratory movements, whether it be performed before or after the section of the Vagi. Dr. Reid found that in a kitten of a day old, in which the inspirations had been 100 per minute, they fell to 40 when the Encephalon was removed; and on subsequently cutting the Pneumogastrics, the number of inspirations instantly fell to between 3 and 4 in the minute, and continued so for some time. Hence it has been supposed that the respiratory movements are partly dependent upon sensation, a motor influence being excited by it; but it may be fairly surmised, from the close dependence of nervous activity upon the oxygenation of the blood, that a 'besoin de respirer' may originate in the circulation of imperfectly-aerated blood in the nervous centres themselves, and may become the direct excitor of respiratory movements.

300. But why (it may be asked) do the movements continue, when the Pneumogastrics have been divided, and the Encephalon has been removed? It is evident that there must be *other* excitors to the action of the respiratory muscles. Amongst these, the nerves distributed to the general surface, and particularly to the face, probably perform an important part, and in exciting the first inspiration, the Fifth pair seems the principal agent. It has long been a well-known fact, that the first inspiratory effort of the new-born infant is most vigorously performed, when the cool external air comes into contact with the face; and that impressions on the general surface, such as a slap of the hand on the nates, are often effectual in exciting the first inspiratory movements, when they would not otherwise commence. Dr M. Hall relates an interesting case, in which the first inspiration was delayed, simply because the face was protected

* "Edinb. Med. and Surg. Journ.," vol. li.; and "Phys., Anat., and Pathol. Res.," p. 177.—Dr. Reid has satisfactorily shown the statement of many experimenters, that the inspirations are *increased* in frequency after this operation, to be erroneous; this idea having originated in the very prolonged and laborious character of the movements.

down, whilst the Facial nerve and the Spinal Accessory, to the latter of which, as will be shown hereafter, (CHAP. XI. Sect. 2), the motor powers of the Pneumogastric are chiefly due, take their origin in the Medulla Oblongata itself. But we must not decide upon the connection of a particular nerve with a particular segment of the Spinal Cord, simply because it diverges from it at that point; and the analogy of the Invertebrated classes favours the idea, that a direct structural connection exists between the ganglionic centre of the Respiratory movements, and the nerves which transmit their influence to the muscles. Upon this point, however, it is unsafe to speculate; and we can only state it as a possibility, that some such connection may be established in Vertebrated animals through the white columns of the spinal cord.

302. That the Respiratory movements, as ordinarily performed, are essentially independent of the Will, appears not only from our own consciousness, but also from cases of paralysis, in some of which, the power of the will over the muscles has been lost, whilst the movements have been kept-up by the reflex action of the Medulla Oblongata or respiratory ganglion; whilst in others, some of the respiratory muscles have been motionless during ordinary breathing, and yet have remained under the power of the will.* That Consciousness is not a necessary link in the chain of causes which produce the respiratory movements, we are enabled to judge from the phenomena presented by the human being in sleep and coma, by anencephalous fœtuses, and by decapitated animals. This conclusion is confirmed by a case recorded by Dr. H. Ley,† who had under his care a patient in whom the pneumogastrics appeared to be diseased; the lungs suffered in the usual way in consequence, and the patient had evidently laborious breathing; but he distinctly said that he felt no uneasiness in his chest. The experience of every one informs him, however, that the Respiratory movements are partly under the control of the will, though frequently unrestrainable by it. In ordinary circumstances, when the blood is being perfectly aerated, and there is a sufficient amount of arterial blood in the system to carry-on the functions of life for a short time, we can suspend the respiratory actions during a few seconds without any inconvenience. If, however, we endeavour to prolong the suspension, the stimulus conveyed by the excitor nerves to the Medulla Oblongata becomes too strong, and we cannot avoid making inspiratory efforts; and if the suspension be still further prolonged, the whole body becomes agitated by movements which are almost of a convulsive nature, and no effort of the will can then prevent the ingress of air.‡ It is easy to understand why, in the higher animals at least, and more especially in

* Such cases are mentioned by Sir C. Bell, in the Appendix to his work on the "Nervous System of the Human Body."

† "On Laryngismus Stridulus," p. 417.

‡ It is asserted by M. Bourdon ("Recherches sur le Mécanisme de la Respiration," p. 21), that no person ever committed suicide, though many have attempted to do so, by simply holding the breath, the control of the will over the respiratory muscles not being sufficiently great to antagonize the stimulus of the "besoin de respirer," when this has become aggravated by the temporary cessation of the action. But such persons have succeeded better, by holding the face beneath the surface of water; because here another set of muscles is called into action, which are much more under the control of the will, than are those of respiration; and a strong volition applied to these can prevent all access of air to the lungs, however violent may be the inspiratory efforts.

animal remains at rest; but an unusual respiratory movement, such as takes place at the commencement of a struggle, induces immediate symptoms of suffocation,—the current of air carrying inwards the arytenoid cartilages, which are rendered passive by the paralysed state of their muscles, and these, falling upon the opening of the glottis, like valves, obstruct the entrance of air into the lungs. The more effort is made the greater will be the obstruction; and accordingly, it is generally necessary to counteract the tendency to suffocation, when it is desired to prolong the life of the animal after this operation, by making an opening into the trachea. Dr. Reid further ascertained, that the application of a stimulus to the inferior laryngeal nerves, when separated from the trunk, would occasion distinct muscular contractions in the larynx; whilst a corresponding stimulus applied to the superior laryngeal occasioned no muscular movement, except in the crico-thyroid muscle. But when the superior laryngeals were entire, irritation of the mucous surface of the larynx, or of the trunks themselves, produced contraction of the glottis and efforts to cough, effects which were at once prevented by dividing those nerves, and thereby cutting off their communication with the Medulla Oblongata. There can be no doubt, then, that the superior and inferior laryngeal branches constitute the circle of incident and motor nerves, by which the aperture of the glottis is governed, and by which any irritation of the larynx is made to close the passage, so as to prevent the entrance of improper substances; whilst the superior laryngeal nerve also excites the muscles of expiration, so as to cause the violent ejection of a blast of air, by which the offending gas, fluid, or solid, may be carried-off. The effect of carbonic acid in causing spasmodic closure of the glottis, is well known; and affords a beautiful example of the protective office of this system of nerves. The mucous surface of the trachea and bronchi appears, from the experiments of Valentin, to be endowed with excitability, so that stimuli applied to it produce expiratory movements; and this evidently operates through the branches of the pneumogastric distributed upon the membrane. Here, as elsewhere, we find that a stimulus applied to the *surface* has a much more decided influence, than irritation of the *trunk* of the nerve supplying it.

305. The actions of *sighing, yawning, sobbing, laughing, coughing,* and *sneezing,* are nothing else than simple modifications of the ordinary movements of respiration, excited either by mental emotions, or by some stimulus originating in the respiratory organs themselves.—*Sighing* is nothing more than a very long drawn inspiration, in which a larger quantity of air than usual is made to enter the lungs. This is continually taking place to a moderate degree; and we notice it particularly when the attention is released, after having been fixed upon an object which has excited it strongly, and which has prevented our feeling the insufficiency of the ordinary movements of respiration. Hence this action is only occasionally connected with mental emotion.—*Yawning* is a still deeper inspiration, which is accompanied by a kind of spasmodic contraction of the muscles of the jaw, and also by a very great elevation of the ribs, in which the scapulæ partake. The purely involuntary character of this movement is sometimes seen, in a remarkable manner, in cases of palsy; in which the patient cannot raise his shoulder by an effort of the

before it anything that may offer an obstruction.—The difference between Coughing and *Sneezing* consists in this,—that in the latter, the communication between the larynx and the mouth is partly or entirely closed by the drawing-together of the sides of the velum palati over the back of the tongue, so that the blast of air is directed, more or less completely, through the nose, in such a way as to carry-off any source of irritation that may be present there.—It is difficult to say how far these actions are independent of consciousness, or how far they may require the stimulus of sensation for their performance.

307. Various alterations are produced in the Lungs, by section of the Pneumogastric nerves; and it has been supposed that these exert some more immediate and direct influence over the condition of those organs than their connection with the respiratory movements will serve to account-for. The inquiry into the nature and succession of these changes has been most carefully prosecuted by Dr J. Reid (Op. cit.), and as the results have a very important bearing on several physiological and pathological questions of great interest, a summary of them will be here given. —In the first place, it has been fully established by Dr. Reid, that section of the Vagus on *one* side only does not necessarily, or even generally, induce disease of that lung; and hence the important inference may be drawn, that the nerve does not exercise any *immediate* influence on its functions. When *both* Vagi are divided, however, the animal rarely survives long, but its death frequently results from the disorder of the digestive functions. Nevertheless, the power of digestion is sometimes restored sufficiently to re-invigorate the animals, and their lives may then be prolonged for a considerable time (§ 102). In fifteen out of seventeen animals experimented-on by Dr. Reid, the lungs were found more or less unfit for the healthy performance of their functions. The most common morbid changes were a congested state of the blood-vessels, and an effusion of frothy serum into the air-cells and bronchial-tubes. In eight out of the fifteen, these changes were strongly marked. In some portions of the lungs, the quantity of blood was so great as to render them dense. The degree of congestion varied in different parts of the same lung; but it was generally greatest at the most depending portions. The condensation was generally greater than could be accounted for by the mere congestion of blood in the vessels, and probably arose from the escape of the solid parts of the blood into the tissue of the lung. In some instances the condensation was so great, that considerable portions of the lung sank in water, and did not crepitate; but they did not present the granulated appearance of the second stage of ordinary pneumonia. In five cases in which the animal had survived a considerable time, portions of the lungs exhibited the second, and even the third stages of pneumonia, with puriform effusion into the small bronchial tubes; and in two, gangrene had supervened.—One of the most important points to ascertain in an investigation of this kind, is the *first departure* from a healthy state; to decide whether the effusion of frothy reddish serum, by interfering with the usual change in the lungs, *causes* the congested state of the pulmonary vessels, and the laboured respiration; or whether the effusion is the *effect* of a previously-congested state of the blood-vessels. The former is the opinion of many physiologists, who have represented the effusion of serum as a process of morbid secre-

and reactions, when he wishes to examine the order and dependence of its phenomena." In such investigations, no useful inference can be drawn from one or two experiments only; in order to avoid all sources of fallacy a large number must be made; the points in which all agree, must be separated from others in which there is a variation of results; and it must be then inquired, to what the latter is due.*

2. *Effects of Respiration on the Air.*

309. The total amount of air which can be drawn into the Lungs by the deepest possible inspiratory movement, by no means affords a measure of the quantity which they ordinarily contain. It is in fact composed, as was first pointed-out by Mr. Julius Jeffreys,† of several different quantities, which may be distinguished as follows:—

1. *Residual Air;* that which cannot be displaced by the most powerful expiration, which always remains in the thorax so long as the lungs retain their natural structure, and over which, therefore, we have no control.

2. *Supplemental Air;* that portion which remains in the chest after the ordinary gentle expiration, but which may be displaced at will.

3. *Breathing* or *Tidal Air*, that volume which is displaced by the constant gentle inspiration and expiration.

4. *Complemental Air;* the quantity which can be inhaled by the deepest possible inspiration, over and above that which is introduced in ordinary breathing.

The amount which can be expelled by the most forcible expiration after the fullest inspiration, and which is consequently the sum of the 2nd, 3rd, and 4th of these quantities, is designated by Dr. Hutchinson‡ as the *Vital Capacity*, being that volume of air which can be displaced by *living movements*. This 'vital capacity' is less dependent than might have been supposed, upon the absolute *dimensions* of the thoracic cavity, being yet more influenced by its *mobility.* Thus of two sets of men of the same height, one measuring 35 inches round the chest, and the other 38 inches, the average vital capacity of the first was found to be [illegible] inches, and that of the second only 226 inches; for notwithstanding the greater absolute capacity indicated by the larger circumference of the latter, the inferior mobility of the chest caused more 'residual air' to remain behind after the deepest expiration. By taking the average of nearly 5000 observations, Dr. Hutchinson has arrived at the very remarkable conclusion (Op. cit., p. 1072), that of all the elements whose variation might be supposed to affect the 'vital capacity,' *Height* alone seems to have any constant relation to it; and that this relation is capable of being expressed in a simple numerical form. The following

* On the important subject of the Mechanism of Respiration, the following Memoirs may be consulted in addition to those already referred to:— Dr. J. Reid's Art. 'Respiration' in "Cyclop. of Anat. and Physiol.," vol. iv.; Dr. Hutchinson in "Med.-Chir. Trans.," vol. xxix.; Dr. Sibson in "Phil. Trans." 1846, "Med. Gaz.," vol. xli., "Med.-Chir. Trans.," vol. xxxi., and "Trans. of Prov. Med. Assoc.," 1850; Beau and Maissiat in "Arch. Gén.," 1842; Mendelssohn "Der Mechanismus der Respiration und Circulation," Berlin, 1845; and Vierordt, Art. 'Respiration' in "Wagner's Handwörterbuch der Physiologie," band ii.

† "Statics of the Human Chest," 1843.

‡ "Cyclop. of Anat. and Physiol.," vol. iv., Art. 'Thorax.'

should be very corpulent) should excite suspicion of disease; but the observations of Dr. C. R. Hall (loc. cit.) seem to show that the range is considerably wider, especially in females. They also indicate that even a marked deficiency in vital capacity must not be regarded as indicative of pulmonary disease; for it may be dependent upon disorder of the abdominal viscera, especially upon congested liver.

311. In estimating, however, the effects of the Respiratory function upon the Air which passes through the lungs, we are not so much concerned with the quantity which *may* be drawn in and forced out, as with that actually exchanged at each movement. There are many difficulties in arriving at any exact conclusion upon this point; and hence it happens that the estimates of those who have inquired into it are singularly discrepant. The following are the amounts assigned by some of the most recent experimenters.

Herbst*		20—30 cubic inches.
Valentin†		14 92 ,,
Vierordt‡		10 42 ,,
Coathupe§		16 ,,
Hutchinson‖	average	16 20 ,,
	extremes	7 77 ,,

If we take 20 cubic inches as the average quantity exchanged at each respiration, we cannot but observe how small a proportion it bears to the entire amount which the lungs usually contain; for the 'residual air,' which cannot be expelled, is estimated by Dr. Hutchinson at from 75 to 100 cubic inches, and the 'supplemental air,' which can only be expelled by a forced expiration, is about as much more; the sum of the two being from 150 to 200 cub. in., or from 7½ to 10 times the 'breathing volume.' Now it is obvious that if no provision existed, for mingling the air inspired with the air already occupying the lungs, the former would penetrate no further than the larger air-passages; and as this would be again thrown-out at the next expiration, the bulk of the air contained in the lungs would remain altogether without renewal, and the expired air would not be found to have undergone any change.¶ That a change *is* effected, however, in the whole volume of the air contained in the lungs, with every inspiration, is indicated by the difference between the inspired and expired air; and this change must be attributed to the 'mutual diffusion' of gases, these tending to interpenetrate one another, when either of different densities or of different temperatures, according to the law discovered by Prof. Graham (§ 314)

312 The *total amount* of Air which passes through the Lungs in twenty four hours, will of course vary with the extent and frequency of the respiratory movements; and these are liable to be affected by many circumstances, but particularly by the relative degrees of repose and of exertion. Moreover, as any such computation must be based upon the datum of the ordinary volume of breathing or 'tidal' air, it is obvious

* "Meckel's Archiv.," 1828.
† "Lehrbuch der Physiologie," band i. p. 538.
‡ "Wagner's Handworterbuch," band ii p. 835.
§ "Philosophical Magazine," 1839, vol. xiv. p. 401.
‖ "Cyclop. of Anat. and Phys," vol iv. p 1067.
¶ See Mr Jeffreys's "Statics of the Human Chest," in which this important point first received due consideration.

that the estimates of different observers must vary with the amount they adopt. Thus Mr. Coathupe's estimate of the diurnal total is 460,800 cub. in., or 366¼ cubic feet; that of Vierordt, from his observations on his own person in a state of rest, is 530,026 cub. in., or 306⅔ cub. feet, but this, when corrected (by Scharling's experiments) for a moderate amount of exertion, would be raised to 624,087 cub. in., or 361 cub. feet, and that of Valentin is as high as 688,348 cub. in., or 398½ cub. feet.—It is of great practical importance to determine the quantity of air which ought to be allowed for consumption by individuals confined in prisons, workhouses, schools, &c.; and for this, experience seems to have fixed 800 cubic feet as the *minimum* that can be safely assigned, except where extraordinary provisions are in operation for its constant renewal by ventilation. The evil consequences of an insufficient supply of air will be noticed hereafter (Sect. 3).

313. The *alterations* in this Air which are effected by Respiration, mainly consist in the removal of a portion of its *oxygen*, and the substitution of a quantity of *carbonic acid*, usually rather less in bulk than the oxygen which has disappeared. The proportion of the air thus changed, appears to vary according to the frequency of the respirations. Thus Vierordt* found that, if he only respired *six* times in a minute, the quantity of Carbonic acid was 5·5 per cent. of the whole air exhaled; with *twelve* respirations, it was 4·2; with *twenty-four*, it was 3·3; with *forty-eight*, it was 3·0; and with *ninety-six*, it was 2·6 per cent. In some of the experiments of Messrs. Allen and Pepys, it was as much as 8 per cent. Probably about 4·35 per cent. may be taken as the average, at the ordinary rate of respiration.—It appears, however, from the researches of the last-named experimenters, that, if the air be already charged in some degree with Carbonic acid, the quantity exhaled is much less; for, when 300 cubic inches of air were respired for *three minutes*, only 28½ cubic inches (9½ per cent.) of carbonic acid were found in it; although the previous rate of its production, when fresh air was taken-in at every respiration, was 32 cubic inches in a minute. Knowing, then, the necessity of a free excretion of carbonic acid, we are led by this fact to perceive the high importance of ventilation; for it is not sufficient for health, that a room should contain the quantity of air requisite for the support of its inhabitants during a given time; since after they have remained in it but a part of that time, the quantity of carbonic acid which its atmosphere will contain, will be large enough to interfere greatly with the due aeration of their blood, and will thus cause oppression of the brain, and the other morbid affections that result from the accumulation of carbonic acid in the circulating fluid.—It appears from the experiments of Dr. Snow, that the presence of Carbonic acid in the atmosphere acts more deleteriously upon the system, in proportion as the normal quantity of Oxygen has been reduced. He found that birds and mammalia, introduced into an atmosphere containing only from 10½ to 16 per cent. of oxygen, soon died, although means were taken to remove the carbonic acid set-free by their respiration, as fast as it was formed; whilst, on the other hand, an increase in the proportion of carbonic acid to 12 or even 20 per cent.—the per-centage of oxygen being kept to its regular

* "Physiologie des Athmens," pp. 102–149.

standard of 21 per cent.—did not appear to enfeeble the vital actions more rapidly, than did the reduction of the oxygen in the experiments just referred to. Dr. Snow concludes, from his experiments on the lower animals, that 5 or 6 per cent. of carbonic acid cannot exist in an atmosphere respired by Man, without danger to life; and that less than half this amount will soon be fatal, when it is formed at the expense of the oxygen of the air.*

314. The reaction which thus takes place between the Air and the Blood, is partly explicable upon physical principles. It has been shown by Prof Graham, that when two gases, of different specific gravities, but not disposed to unite chemically, are separated by a porous septum, each will tend to diffuse itself through the other; the amount of each that will traverse the septum (or its 'diffusion volume'), being to that of the other, inversely as the square roots of their respective specific gravities. According to this law, the volume of Oxygen that is taken-in, should exceed that of the Carbonic acid which passes-out, in the proportion of 1174 to 1000, and it has been attempted by Valentin and Brunner† to show, that, if a reasonable allowance be made for accidental causes of disturbance, this is the actual proportion between the Oxygen absorbed and the carbonic acid given-out, as indicated by experiment. Such, however, cannot be the case, since the departures are too wide to be accounted-for on this hypothesis; and it is easy to see that other conditions must have an important influence in modifying the action. For, in the first place, the membranous septum is not freely exposed to gases on both sides; but, whilst one surface is in contact with the atmosphere, the other is in contact with a liquid containing gases, these being either in solution, or in a state of loose chemical combination. With regard to that part of the gases of the blood, which is simply absorbed mechanically, it seems probable that the law of Henry and Dalton holds good; viz., that the volume of gas absorbed by a liquid depends entirely upon the pressure under which the gas above it remains after the absorption has been completed; and that, in the case of mixed gases, this proportion is determined by the tension of each individual gas. The quantity of carbonic acid passing from the blood to the air-cells would therefore depend, on the one hand, upon the excess of this gas condensed in the blood; and, on the other, upon the tension of the carbonic acid gas already contained in the atmosphere of the air-cells. Conversely, the blood when it enters the lungs not being saturated with oxygen, is able to absorb a larger quantity under the pressure which it there experiences, the tension of the oxygen contained in the air-cells being considerable.—In so far as this law is in operation, then, the passage of each gas is independent of that of the other; but it does not apply to the gases that are in any kind of chemical combination with the constituents of the blood; and further, it seems likely that any physical forces of the kind adverted-to must be modified in their action by the difference of permeability which animal membranes possess for different gases.

315. The recent experiments of MM. Regnault and Reiset‡ appear

* "Edinb. Med. and Surg. Journal," 1846.
† Valentin's "Lehrbuch der Physiologie," band i. pp. 507-580.
‡ "Annales de Chimie et de Physique," 1849.

to have furnished the solution of the wide differences in the estimates which various experimenters have given, as to the relative amount of Oxygen absorbed and of Carbonic acid exhaled; by showing that it depends,—not, as Dulong and Despretz supposed, upon the kind of *animal* (the proportion of oxygen absorbed being much larger in Carnivora than in Herbivora),—but upon the nature of the *aliment* on which the animal is fed at the time of the experiment. Animals fed on flesh absorb much more oxygen in proportion, than those fed on a vegetable diet; thus in a dog exclusively nourished on flesh, the proportion of oxygen absorbed, to 100 parts of carbonic acid exhaled, was 134·3, or much *above* that which the law of mutual diffusion would indicate; whilst in a rabbit fed exclusively upon vegetable food, the proportion of oxygen absorbed was only 109·34 to 100 parts of carbonic acid exhaled, or *less* than the calculated amount. The difference between the relative proportions of surplus Oxygen, in the same animal, under opposite circumstances, was found to be as much as 62 : 104. It is not difficult to account for these diversities, when we bear in mind the different composition of the saccharine carbo-hydrates, of oleaginous substances, and of bodies of the albuminous type. For as, in *sugar*, *starch*, &c., the hydrogen is already provided with its equivalent of oxygen, the carbonic acid generated by their combustion will contain the whole bulk of the oxygen consumed; and hence the small per-centage of oxygen which disappears in the respiration of herbivorous animals, must be appropriated to other purposes in their economy. But when the material consumed is *fat*, the oxygen contained in the carbonic acid that is generated will be only 71·32 per cent. of the whole amount that disappears; the remaining 28·68 per cent. being appropriated by the surplus hydrogen (that, namely, for which the substance contained no equivalent of oxygen) to form water. And in like manner, when the material consumed is *muscular substance*, only 83·60 per cent. of the oxygen that disappears will be found in the carbonic acid generated; the remaining 16·40 forming water with the surplus hydrogen.* The disappearance of oxygen, even in Herbivorous animals, is thus accounted for by the circumstance, that part of the materials of their respiration are furnished by the disintegration of their own tissues; with regard to which, therefore, they are on the footing of Carnivorous animals. And this view is borne-out by the curious fact ascertained by MM. Regnault and Reiset, and confirmed by other experimenters, that when an animal is kept fasting, the relation between the Oxygen absorbed and the Carbonic acid exhaled is nearly the same as when the animal is fed on flesh; the reason apparently being, that in the former case the animal's respiration is kept up at the expense of the constituents of its own body, which correspond with animal food in their composition.—There can be no doubt, then, that, on the whole, a considerable surplus of oxygen is absorbed into the system: and whilst a part of this additional oxygen is made to combine with Hydrogen furnished by the food or by the disintegration of the tissues, the water thus generated forming part of that exhaled from the lungs, another part will be applied to the oxidation of the Sulphur and Phosphorus, which are taken-in as such in the food, and which, after

* See Prof. Lehmann's "Lehrbuch der Physiologischen Chemie," band iii. p. 314.

forming part of the solid tissues, are excreted in the condition of sulphuric and phosphoric acids, chiefly through the kidneys. It also appears, from the recent experiments of Dr. Bence Jones,* that the action of oxygen is exerted in the system upon Ammonia, and probably upon other products of decomposition of the nitrogenous tissues, in such a manner as to produce Nitrous or Nitric acid, which makes its appearance in the urine.

316. The absolute quantity of Carbonic Acid exhaled from the Lungs is liable to variation from so many sources, that no fixed standard can be assigned for it. The mean of a great number of observations, however made in different modes, and under different circumstances, would give about 160 grains of Carbon per hour as the amount set-free by a well grown adult man, under ordinary circumstances. Taking this as the average of the twenty-four hours, the total quantity of Carbon thus daily expired from the Lungs would be 3840 grains, or 8 oz. Troy. The chief causes of variation are,—the Temperature and Hygrometric state of the surrounding Medium, Age, Sex, Development of the body, Nature and Quantity of Food and state of the Digestive Process, Muscular Exertion or Repose, Sleep or Watchfulness, Period of the Day, and state of Health or Disease. These will now be considered in detail.—

I. *Temperature of surrounding Medium.*—The amount of Carbonic Acid exhaled by warm-blooded animals, is greatly *increased* by external *Cold*, and *diminished* by *Heat*, as is shown by the following results of comparative experiments upon the quantity set-free by the same animals, at low, medium, and high temperatures, in periods of an hour (Letellier†):—

	Temp about 32°. *Grammes*	Temp 59°—68°. *Grammes.*	Temp 86°-106° *Grammes*
A Canary . .	0·325	0·250	0·129
A Turtle Dove	0·974	0·684	0·33[illegible]
Two Mice	0·531	0·438	0·26[illegible]
A Guinea-Pig	3·006	2·080	1·455

From this table it appears that the quantity of carbonic acid exhaled by Mammals between 86° and 106°, is less than *half* that set-free near the freezing-point; whilst that which is exhaled between 59° and 68° is but little more than *two-thirds* of the same amount. The diminution occasioned by heat is still more remarkable in Birds; which exhale at the highest temperature scarcely more than *one-third* of that set-free at the lowest.—The observations of Vierordt‡ upon himself show that the same is true of the Human subject; a difference of 10° Fahr., according to him, producing a variation of rather more than two cubic inches in the amount of Carbonic Acid hourly expired.

II. That the *Hygrometric state of the Air* influences the rate of exhalation of Carbonic Acid, appears from some experiments of Lehmann's made with this express view. For he found that while 1000 grammes weight of Pigeons yielded, in *dry* air, 6·055 grammes of carbonic acid per hour, at the temperature of 75°, and 4·69 grammes at the tempe-

* "Philosophical Transactions," 1851; and "Medical Times," Aug. 30, 1851

† "Annales de Chimie et de Physique," 1845; and, M Boussingault's "Memoires de Chimie Agricole et de Physiologie," 1854.

‡ "Physiologie des Athmens," pp. 73—82.

rature of 100°, the same animals, in *moist* air, yielded 6·769 grammes at 73°, and 7·76 grammes at 100°. And while 1000 grammes' weight of Rabbits exhaled, in *dry* air, 0·451 gramme per hour, at a temperature of 100°, they exhaled as much as 0·677 gramme in a *moist* atmosphere at the same temperature.*

III. *Age.*—The amount of Carbonic Acid exhaled increases in both sexes up to about the thirtieth year; it remains stationary until about the forty-fifth; and it then diminishes. The following are the comparative results of experiments upon males of different ages, and of a moderate degree of muscular development (Andral and Gavarret†):—

Age.	*Carbon exhaled per hour.*	*Age.*	*Carbon exhaled per hour.*
8 years	77·0 grains.	37 years	164 7 grains.
12 ,,	113 9 ,,	48 ,,	161·7 ,,
14 ,,	126 2 ,,	59 ,,	154·0 ,,
20 ,,	166·3 ,,	68 ,,	147 8 ,,
26 ,,	169·4 ,,	76 ,,	92 4 ,,

IV. *Sex.*—At all ages beyond eight years, the exhalation is greater in Males than in Females. Nearly the same proportionate increase takes place, however, in Females, up to the time of puberty; when the quantity abruptly ceases to increase, and remains stationary so long as they continue to menstruate. When, however, menstruation has ceased, the exhalation of carbonic acid begins again to augment; and then again diminishes, with the advance of years, as in men. Should menstruation temporarily cease at any time, the exhalation of carbonic acid immediately undergoes an increase, precisely as at the final cessation of the function. And during pregnancy, the exhalation increases in like manner. The following table of the comparative respiration of Females at different ages will serve at the same time for comparison with the preceding, so as to exhibit the general difference between the two sexes, at ages nearly corresponding; and also to indicate the peculiar modifications induced by the operations of the genital system (Andral and Gavarret):—

Age.	*Carbon exhaled per hour.*	*Age.*	*Carbon exhaled per hour.*
10 years	92·4 grains.		
13 ,,	97 0 ,,		
During Menstrual life.		During Pregnancy.	
15½ years	97·0 grains.	22 years	129·3 grains
26 ,,	97·0 ,,	32 ,,	126·7 ,,
32 ,,	95·4 ,,	42 ,,	120·3 ,,
45 ,,	95 4 ,,		
After Cessation of Catamenia.			
38 years	120·3 grains.	66 years	104·7 grains.
49 ,,	113 9 ,,	76 ,,	101 4 ,,
52 ,,	115 5 ,,	82 ,,	92·4 ,,
56 ,,	119·3 ,,		

V. *Development of the Body.*—The more robust the individual, *cæteris paribus*, the more carbonic acid is exhaled; and the variation is much more influenced by the development of the muscular system, than

* Lehmann, Op. cit., band iii, p. 304.
† "Annales de Chimie et de Physique," 1843.

[illegible] the height or weight [illegible] Thus, a very stron[g] man of twenty-six [illegible] of [illegible] grains p[er] hour, while a man [illegible] grai[ns] in the same time [illegible] years of age exhaled [at] the rate of [illegible] and sixty-three years [illegible] and an old ma[n] of ninety-[illegible] degree of energy, and who [illegible] muscul[ar] powers [illegible] also, [a] remark[able] [illegible] at the rat[e] of [illegible] rather le[ss] [illegible] forty-fo[ur] years [illegible] the oth[er] [illegible] of goo[d] [illegible] Austral an[d] [illegible]

[illegible] *Pr[illegible]*

[illegible] greatly [illegible] Thus Prof. [illegible] instance [illegible] 140 to [illegible] after [illegible] again, [illegible] on an [illegible] its full [illegible] acid [illegible] amount of [illegible] results [illegible] that when [illegible] portion [illegible] ination, [illegible] per cent. [illegible] rate of [illegible] and [illegible] pro- [illegible] there [illegible] relation [illegible] may [illegible] which have [illegible] thus dimi- [illegible] assumed in the [illegible]

one third of a cubic inch of carbonic acid, in the course of a single
ing which its whole body was in a state of constant movement,
excitement resulting from its capture; and yet, during the whole
in hours of the succeeding day, which it passed in a state of
ive rest, the quantity of carbonic acid generated by it was
y less.

leep or Watchfulness.—The amount of carbonic acid exhaled
eep is considerably less than that set-free in the waking state,
rticularly shown by the experiments of Scharling,† who confined
ets of them in an air-tight chamber, within which they could
e their meals, &c. Thus in one case the hourly exhalation sank
to 100, in another from 194·7 to 122·3, and in another from
1. The cause of this result is partly to be sought in the cessation
scular exertion (save that concerned in the maintenance of the
n); and partly in the diminution in the dissipation of the heat
dy itself.

riod of the Day.—Independently of these variations, which have
ce in the condition of the individual, there is reason to believe
e is a diurnal cycle of change in the quantity of carbonic acid
the *maximum* being (cæteris paribus) before and after noon, and
mum before and after midnight. From the experiments of
g upon the Human subject, it would appear that the average
n exhaled by day to that exhaled by night, is as 1¼ to 1; and this
does not seem to be affected by sleep or wakefulness. How far
be accounted-for by other differences in the condition of the
t, does not seem easy to determine. But it is pretty obviously
d with a difference in the power of generating heat; for accord-
he observations of Chossat (CHAP. X.), there is a like diurnal
in the temperature of Birds; and most persons are conscious of
difficulty in bearing exposure to cold between midnight and

by the height or weight, capacity of the chest, &c. Thus, a very strong man of twenty-six years of age exhaled at the rate of 217·1 grains per hour, while a man of moderate muscular power set-free but 169·4 grains in the same time. Another robust man of sixty years of age exhaled at the rate of 209·4 per hour; another of similar constitution, and sixty-three years of age, at the rate of 190·9 grains per hour, and an old man of ninety-two years, who still preserved an uncommon degree of energy, and who in his younger days had boasted of extraordinary muscular powers, exhaled at the rate of 135·5 grains per hour. So, also, a remarkably vigorous young woman of nineteen years, exhaled at the rate of 107·8 grains per hour; another of twenty-two years, rather less powerful, at the rate of 103·1 grains, and a strong woman of forty-four years (who had ceased to menstruate) 152·4 grains.—On the other hand, a slender man of forty-five years, in the enjoyment of good health, only exhaled at the rate of 132·4 grains per hour (Andral and Gavarret).

VI. *Nature and Quantity of the Food, and State of the Digestive Process.*—It is well established, that the exhalation of carbonic acid is greatly increased by eating, and that it is diminished by fasting. Thus Prof. Scharling states the hourly exhalation to have increased in one instance from 145 to 190, after breakfast and a walk; in another from 140 to 177, after breakfast alone; and in another from 111·9 to 188·9, after dinner. The observations of Vierordt are to the same effect. So, again, it has been found by Bidder and Schmidt, that whilst a Cat, fed on an allowance of meat which was found to be adequate to maintain its full strength and ordinary weight, exhaled 65·60 grammes of carbonic acid per diem, the same animal, consuming nearly double that amount of food, exhaled nearly double the amount of carbonic acid. Similar results were obtained by MM. Regnault and Reiset, who found that when animals were over-fed with the saccharine hydrocarbons, the proportion of the carbonic acid exhaled, to that of the other products of combustion, underwent such an increase, that it contained 95 or even 99·7 per cent. of the oxygen which had disappeared.—On the other hand, the use of Alcoholic drinks tends to *diminish* the exhalation of carbonic acid; and this not merely (as maintained by some) in virtue of the large proportion of surplus hydrogen contained in alcohol, but also (as there appears strong reason to believe) by obstructing the normal oxidation and elimination of other combustible materials which the blood may contain. For it is shown by the experiments of Dr. Prout,* which have been confirmed as to many points by those of Vierordt, that this diminution continues so long as the alcohol remains unconsumed in the system, and is then followed by a marked *increase* in the per-centage of carbonic acid in the inspired air.

VII. *Muscular Exertion or Repose.*—The effect of bodily exercise, in moderation, is to produce a considerable increase in the amount of carbonic acid exhaled, both during its continuance, and for some little time subsequently to its cessation. According to the observations of Vierordt, the increase amounts to one-third of the quantity exhaled during rest; and it lasts for more than an hour afterwards, being manifested in the

* "Thomson's Annals of Philosophy," vols. ii. and iv.

greater quantity of air respired, and in the larger per-centage of carbonic acid contained in it. If the exercise be prolonged, however, so as to occasion fatigue, it is succeeded by a diminished exhalation.—The connection between muscular exertion and the exhalation of carbonic acid, is most remarkably shown in Insects; in which animals we may witness the rapid transition between the opposite conditions of extreme muscular exertion, and tranquil repose; and in which the effects of these upon the respiratory process are not masked by that exhalation of carbonic acid, which is required in warm-blooded animals simply for the maintenance of a fixed temperature. Thus a Humble-Bee was found by Mr. Newport* to produce one third of a cubic inch of carbonic acid, in the course of a single hour, during which its whole body was in a state of constant movement, from the excitement resulting from its capture; and yet, during the whole twenty four hours of the succeeding day, which it passed in a state of comparative rest, the quantity of carbonic acid generated by it was absolutely less.

VIII. *Sleep or Watchfulness.*—The amount of carbonic acid exhaled during sleep, is considerably less than that set-free in the waking state. This is particularly shown by the experiments of Scharling;† who confined the subjects of them in an air-tight chamber, within which they could sleep, take their meals, &c. Thus in one case, the hourly exhalation sank from 160 to 100, in another from 194·7 to 122·3, and in another from 99 to 75·1. The cause of this result is partly to be sought in the cessation of all muscular exertion (save that concerned in the maintenance of the respiration), and partly in the diminution in the dissipation of the heat of the body itself.

IX. *Period of the Day.*—Independently of these variations, which have their source in the condition of the individual, there is reason to believe that there is a diurnal cycle of change in the quantity of carbonic acid exhaled, the *maximum* being (cæteris paribus) before and after noon, and the *minimum* before and after midnight. From the experiments of Scharling upon the Human subject, it would appear that the average proportion exhaled by day to that exhaled by night, is as 1¼ to 1; and this difference does not seem to be affected by sleep or wakefulness. How far it is to be accounted-for by other differences in the condition of the system, it does not seem easy to determine. But it is pretty obviously associated with a difference in the power of generating heat; for according to the observations of Chossat (CHAP. X.), there is a like diurnal variation in the temperature of Birds; and most persons are conscious of a greater difficulty in bearing exposure to cold between midnight and early morning, than at any other period in the twenty-four hours.

X. *State of Health or Disease.* Upon this very important cause of variation, few accurate researches have yet been made. The *per-centage* of carbonic acid in the expired air has been found to be unusually great in the Exanthemata, and in chronic Skin-diseases (Macgregor‡), and it has been stated to be diminished in Typhus (Malcolm§).—Thus, the average proportion in health being about 4·3 per cent (Vierordt), it has been seen at 8 per cent. in confluent Small-pox, at 5 per cent. in Measles, and at

* "Philos. Transact.," 1836.
† "Ann. der Chem. und Pharm.," 1843; transl. in 'Ann. de Chim. et de Phys.,' 1843.
‡ "Edinb. Monthly Journal," 1843. § "Report of Brit. Assoc.," 1843, p. 87.

7·2 per cent. in a severe case of Ichthyosis which terminated fatally; whilst in Typhus the per-centage has been found to range from 1·18 to 2·50. But these statements do not indicate the total quantity exhaled in each case.—The remarkable increase of the exhalation in cases of Chlorosis, has been already noticed; in four cases recorded by Hannover, the hourly expiration was 123·6, 118·6, 116·9, and 106·3 grains, the absolute quantity diminishing as the respirations increased in rapidity.—In chronic diseases of the respiratory organs, as might be anticipated, the amount of Carbonic acid exhaled undergoes a sensible diminution (Nysten* and Hannover†). —Further researches are much needed on this subject; but, for obvious reasons, they cannot be readily made in severe forms of disease.

317. The aeration of the blood may take place, not only by means of the Lungs, but also in some degree through the medium of the Cutaneous surface. In some of the lower tribes of animals, indeed, this is a very important part of their respiratory process: and even in certain Vertebrata, the cutaneous respiration is capable of supporting life for a considerable time. This is especially the case in the Batrachia, whose skin is soft, thin, and moist; and the effect is here the greater, since, from the small proportion of the blood that has passed through the lungs, that which circulates through the system is very imperfectly arterialized. By the experiments of Bischoff it was ascertained that, even after the lungs of a Frog had been removed, a quarter of a cubic inch of carbonic acid was exhaled from the skin, in the course of eight hours. Experiments on the Human subject leave no room for doubt, that a similar process is effected through the medium of his general surface, although in a very inferior degree; for by confining the body in a close chamber, into which the products of cutaneous respiration could freely pass, whilst the pulmonary respiration was measured by a distinct apparatus, Prof. Scharling‡ ascertained that the proportion of carbonic acid given-off by the Skin is from 1-30th to 1-60th of that exhaled from the Lungs during the same period of time. Moreover, it has been observed, not unfrequently, that the livid tint of the skin which supervenes in Asphyxia, owing to the non-arterialization of the blood in the lungs, has given place after death to the fresh hue of health, owing to the reddening of the blood in the cutaneous capillaries by the action of the atmosphere upon them; and it does not seem improbable that, in cases of obstruction to the due action of the lungs, the exhalation of carbonic acid through the skin may undergo a considerable increase; for we find a similar disposition to vicarious action in other parts of the excreting apparatus. Moreover, there is evidence that the interchange of gases between the air and the blood, through the skin, has an important share in keeping-up the temperature of the body (CHAP. X.); and we find the temperature of the surface much elevated in many cases of pneumonia, phthisis, &c., in which the lungs seem to perform their function very insufficiently.

318. The total amount of Carbonic acid daily given-off from the Skin and Lungs may be estimated in another mode; namely, by determining the total amount of Carbon contained in the *ingesta*, and the amount

* "Recherches de Physiologie et de Chimie Pathologique," 1811.

† "De Quantitate relativa et absoluta Acidi Carbonici ab Homine Sano et Ægroto exhalati," 1845.

‡ "Ann. der Chem. und Pharm.," 1846.

excreted in other ways, making allowance for the difference in weight (if any) of the body. In this mode, Prof. Liebig came to the conclusion, that the average amount of carbon exhaled by soldiers in barracks, was 13·9 oz. (Hessian) or very nearly 14 oz. troy.* From similar collective observations upon the inmates of the Bridewell at Marienschloss (a prison where labour is enforced), he calculates that each individual exhaled 10·5 oz. of carbon daily in the form of carbonic acid; while in a prison at Giessen, whose inmates are deprived of all exercise, the daily average was but 8·5 oz.† It has been shown by Prof. Scharling,‡ that the total amount of carbon contained in the daily allowance of food and drink in the Danish Navy, is somewhat less than 10·5 oz.; and as we shall presently see that from 1-10th to 1-12th of the carbon ingested passes-off through other channels, scarcely more than 9·5 oz. of this amount can be consumed by the respiratory process.—A very exact estimate, though based on more limited data, has been recently made by M. Barral;§ who experimented upon himself (æt. 29) in winter (A) and in summer (B), upon a boy of 6 years old (C), upon a man of 59 years old (D), and upon an unmarried woman of 32 years (E). The following table gives the results which he obtained, from an average of five days, in regard to the disposal of the Carbon of the food; those which relate to its Nitrogen, Hydrogen, and Oxygen will be noticed subsequently (§§ 320, 321).

	Weight of Body	*Carbon of Food.*	*Carbon excreted*		
			In Fæces	In Urine	By exhalation
A	104·5 lbs.	5654·1 grs.	230·2 grs.	234·6 grs.	5183·3 grs.
B	-	4090·0 ,,	137·4 ,,	211·5 ,,	3741·1 ,,
C	33 ,,	2382·8 ,,	149·7 ,,	67·9 ,,	2164·7 ,,
D	129·1 ,,	5123·0 ,,	210·0 ,,	327·3 ,,	4585·7 ,,
E	134·6 ,,	4520·8 ,,	64·8 ,,	216·1 ,,	4239·9 ,,

Thus the average amount of the carbon daily consumed in pulmonary and cutaneous exhalation by M. Barral himself, was in winter 5183·3 grains, or 10·8 oz. troy; whilst in summer it was but 3741·1 grains, or 7·8 oz. troy; this difference is quite conformable to what might have been anticipated from the results of a different mode of experimenting (§ 316 I); and it throws some light on the discrepancies in the results of other measurements, to find that the seasonal variation is scarcely less than one-third of the mean between these two amounts. The other results correspond closely with the statements of MM. Andral and Gavarret, in regard to the higher proportion of carbonic acid exhaled (as compared with the bulk of the body) by children, and the smaller proportion thrown off by men advanced in years, and by women.

319. It is not only by an oxygenated atmosphere, that the removal of Carbonic acid from the blood may be effected. For although it was for-

* "Animal Chemistry," 3rd edit. p. 13.—The mode in which this estimate was made, however, was very far from exact, as it rests on the assumption that the carbon of the fæces and urine was no more than equal to that of certain *extra* articles of diet supposed to have been consumed, and that *all* the carbon of the regular allowance of bread, meat, and vegetables, must have passed-off by the atmosphere. Its great discordance with other results leaves little room for doubt, that even if not far from being true for the particular case, it cannot be admitted as representing the usual average.

† Op. cit. p. 46.

‡ "Ann. der Chem. und Pharm.," 1846.

§ "Ann. de Chim. et de Phys.," tom. xxv

merly supposed that the exhaled carbonic acid is generated in the lungs by the combination of atmospheric oxygen with the carbonaceous matter of the blood, and that the inhalation of oxygen is therefore immediately necessary for its production, yet it is now quite certain that this carbonic acid exists preformed in venous blood, and that the oxygen introduced is carried into the arterial circulation, instead of being at once returned to the air in the state of carbonic acid (§ 179). Hence an exhalation of carbonic acid may continue for a considerable period (in cold-blooded animals especially), whilst the animal is breathing an atmosphere in which no oxygen exists. Thus it was shown by Spallanzani,* that Snails might be kept for a long time in Hydrogen, without apparent injury to them, and that during this period they disengaged a considerable amount of Carbonic acid. Dr. Edwards† subsequently ascertained that, when Frogs were kept in hydrogen for several hours, the quantity of carbonic acid exhaled was fully as great as it would have been in atmospheric air or even greater; this latter fact, if correct, may be accounted-for by the superior displacing power, which (on the laws of the diffusion of gases) hydrogen possesses for carbonic acid. Collard de Martigny‡ repeated this experiment in Nitrogen, with the same results. In both sets of experiments, the precaution was used of compressing the flanks of the animal previously to immersing it in the gas, so as to expel from the lungs whatever mixture of oxygen they might contain. These experiments have been since repeated by Muller and Bergemann, who took the additional precaution of removing, by means of the air-pump, all the atmospheric air that the lungs of the frog might previously contain, together with the carbonic acid that might exist in the alimentary canal. They found in one of their experiments, that the quantity of carbonic acid exhaled in hydrogen was nearly a cubic inch in 6½ hours; and in another, that nearly the same amount was given-off in nitrogen, though this required rather a longer period. It appears from the table of their results,§ that the amount was not ordinarily greater in the experiments which were prolonged for twelve or fourteen hours, than in those which were terminated in half the time; hence it may be inferred, that the quantity which the blood is itself capable of disengaging is limited, and that the absorption of oxygen is necessary to enable carbonic acid to be continuously set-free from the body.—It is impossible, however, for an *adult* Bird or Mammal to sustain life for any considerable time in an atmosphere deprived of oxygen; since the greatly increased rapidity and energy of all their vital operations, necessitate a much more constant supply of this vivifying agent, than is needed by the inferior tribes; and, as we shall presently see, the capillary action requisite for the passage of the blood through the lungs will not take place without it (§ 327). But Dr Edwards has shown, that *young* Mammalia can sustain life in an atmosphere of hydrogen or nitrogen, for a sufficient length of time to exhale a sensible amount of carbonic acid; so that the character of the process is clearly proved to be the same in warm-blooded animals, as in Reptiles and Invertebrata.

320. Much discussion has taken place, with regard to the degree in

* "Mémoires sur la Respiration," traduits par Senebier, Genève, 1804.
† "De l'Influence des Agens Physiques sur la Vie," Paris, 1824.
‡ "Recherches Expérimentales," &c. in Magendie's "Journal de Physiologie," tom. x.
§ "Muller's "Elements of Physiology," translated by Baly, vol. i., p. 338.

which the proportion of *Nitrogen* in the air is affected by Respiration. It seems probable that the absorption and exhalation of this gas are continually taking place; but that the two amounts usually nearly balance each other.* On the whole, however, there is adequate reason to believe that Nitrogen is ordinarily given-off, this being the joint result of the analysis of the expired air, and of the comparison of the amount of nitrogen given-off in the other excretions with that ingested as a constituent of the food. Of the experiments made in the former of these methods, the most accurate are those of MM. Regnault and Reiset, whose general conclusions are as follows:—(1). That warm-blooded animals subjected to their ordinary regimen exhale nitrogen, but never in larger proportion than 1 50th, and sometimes in less than 1 100th, of the oxygen consumed.—(2). That in a state of inanition, animals usually absorb nitrogen.—(3). That animals whose usual diet has been changed, usually absorb oxygen until they are accustomed to their new food.†—Of the experiments made according to the second method, those of M. Boussingault upon turtle-doves, and those of M. Barral upon the human subject, appear to be trustworthy. The former states that the surplus of nitrogen in the food of the bird, above that excreted by the kidneys and intestinal canal, is 2¼ grains daily, or one-third of the weight of the azote in its food,‡ whilst the latter gives the following as the results of his observations upon himself and the other individuals already referred-to (§ 318):

	Nitrogen in Food.	*Nitrogen excreted.*		
		Urine.	Fæces.	Lungs and Skin.
A	432 3 grs.	168 3 grs.	43 2 grs.	220 8 grs.
B	327·3 ,,	151·3 ,,	20·1 ,,	155·9 ,,
C	121·9 ,,	47·8 ,,	27·8 ,,	46 3 ,,
D	421 5 ,,	234·6 ,,	38·6 ,,	148·3 ,,
E	345·8 ,,	154·4 ,,	12·3 ,,	179·1 ,,

In cases A, B, and E, the amount of Nitrogen which (being otherwise unaccounted for) must be considered to have passed-off by the lungs and skin, was about 1-75th of the oxygen consumed, a proportion which accords very well with that deduced by MM. Regnault and Reiset from their experiments on animals. In case D, however, it was only 1-97th; and in case C (that of a child of six years old), it was as little as 1 143rd.—It will be remembered that Nitrogen exists in an uncombined state in the blood (§ 179), its per-centage, however, is continually varying; and no constant difference is observable between the proportions yielded by arterial and venous blood respectively.

[The alterations effected in the *Blood* by Respiration have already been fully considered. See §§ 179-182.]

321. *Exhalation and Absorption through the Lungs.*—The Air expired from the lungs differs from that which was introduced into them, not merely in the altered proportions of its Oxygen, Nitrogen, and Carbonic acid, but also in having received (under ordinary circumstances at least) a large addition to its watery vapour. This it doubtless acquires in

* For the considerations which render this probable, see especially Dr. W. F. Edwards "On the Influence of Physical Agents on Life," Part iv, chap. xvi. sect. 2, 3.

† "Ann. de Chim. et de Phys.," 1849, and "Mem. de Chim. Agric.," 1854, p. 31.

‡ "Comptes Rendus," 1846.

accordance with physical laws, through its exposure to the warm blood which is spread-out over a very extensive surface, the intermediate membrane being extremely permeable; and the variations in its amount will depend upon the physical conditions under which that exposure takes place. The air expired in ordinary respiration is charged with as much watery vapour as saturates it at the temperature of the body; and consequently the amount of watery vapour thus exhaled, will vary (for equal volumes of air at any given temperature) in the inverse proportion to that which the air previously contained. But when the air is very cold and very dry, and the respiration is unusually rapid, it may not remain sufficiently long in the air-cells, to be raised to the temperature of the body, or to be fully saturated with moisture. The amount of watery vapour exhaled, moreover, will of course depend in part upon the quantity of air which passes through the lungs. And from these causes of difference, it happens that the amount of watery vapour exhaled in twenty-four hours may vary from about 6 oz. to 27 oz.; its usual range, however, being between 16 and 20 oz.—Of the fluid ordinarily exhaled with the breath, a part doubtless proceeds from the moist lining of the nostrils, fauces, &c.; but it is indisputable that the greater proportion of it comes from the lungs, since, when the respiration is entirely performed through a canula introduced into the trachea, the amount of watery vapour which the breath contains is still very considerable. Of the proper pulmonary exhalation, there can be no doubt that the greater part is the mere surplus-water of the blood, and especially of the crude fluid which has been newly introduced into the circulating current by the process of nutritive absorption. But there is strong evidence that Hydrogen as well as carbon undergoes combustion in the system; and that a portion of the exhaled aqueous vapour is the product of that combustion. For of the hydrogen which the food contains, not more than from 1-8th to 1-10th passes off by the other excretions, the remaining 7-8ths or 9-10ths being exhaled in the condition of watery vapour from the lungs. A portion of the oxygen which this vapour contains, is supplied by the food; but there is usually a considerable surplus of hydrogen; and this can only be converted into water, at the expense of oxygen derived from the atmosphere. Upon this point the experiments of M. Barral (loc. cit.) gave the following results:—

	Oxygen exhaled	*Equiv. of Hydrogen.*	*Hydrogen exhaled*	*Difference*
A	3841·4 grs.	480·2 grs.	801·3 grs.	321·1 grs.
B	2757·6 ,,	344·7 ,,	597·5 ,,	252·8 ,,
C	1880·6 ,,	235·1 ,,	330·4 ,,	95·3 ,,
D	3795·1 ,,	474·4 ,,	662·3 ,,	187·9 ,,
E	3140·5 ,,	392·5 ,,	643·8 ,,	251·3 ,,

Thus it appears that, of the Hydrogen exhaled from the lungs and skin of M. Barral, in the condition of watery vapour, not less than 321·1 grs. in winter, and 252·8 grains in summer, must have been converted into water by oxygen derived from the air; and this calculation would give 2889·9 grs. (6 oz. troy) for the winter, and 2275·2 grs. (4·7 oz. troy) for the summer, as the amount of water thus generated in the combustive process. This, however, can only be regarded as an approximation to the truth, since there are many circumstances not taken into account in the computation, by which the estimate may be affected.

322. The fluid thrown-off from the lungs is not pure Water. It holds in solution, as might have been expected, a considerable amount of carbonic acid, and also some animal matter; the exact nature of the latter, which according to Collard de Martigny (op. cit.) constitutes about 3 parts in 1000, has not been ascertained; but from the inquiries of Mr. R. A. Smith,* it would appear to be an albuminous substance in a state of decomposition. If the fluid be kept in a closed vessel, and be exposed to an elevated temperature, a very evident putrid odour is exhaled by it. Every one knows that the breath itself has, occasionally in some persons, and constantly in others, a fœtid taint: when this does not proceed from carious teeth, ulcerations in the air-passages, disease in the lungs, or other similar causes, it must result from the excretion of the odorous matter, in combination with watery vapour, from the pulmonary surface. That this is the true account of it, seems evident from the analogous phenomenon of the excretion of turpentine, camphor, alcohol, and other odorous substances, which have been introduced into the venous system, either by natural absorption, or by direct injection; and also from the suddenness with which it often manifests itself, when the digestive apparatus is slightly disordered, apparently in consequence of the entrance of some mal-assimilated matter into the blood. Among the substances occasionally thrown-off by the lungs, Phosphorus deserves a special mention, on account of the peculiarity of the form under which it is eliminated; for it has been found that if phosphorus be mixed with oil, and be injected into the blood-vessels, it partly escapes in an unoxidized state from the lungs, rendering the breath luminous.† And this luminous breath has also been observed in spirit-drinkers; in whom the oxidation of the effete matters of the system is impeded, in consequence of the demand set-up by the alcohol ingested for the oxygen introduced (§ 316 VIII.)

323. Not only exhalation, but also (under peculiar circumstances) *absorption* of fluid may take place through the Lungs. Thus Dr. Madden‡ has shown that, if the vapour of hot water be inhaled for some time together, the total loss by exhalation is so much less than usual, as to indicate that the cutaneous transpiration is partly counterbalanced by pulmonary absorption; the pulmonary exhalation being at the same time entirely checked. It is probable that, if the quantity of fluid in the blood had been previously diminished by excessive sweating, or by other copious fluid secretions, the pulmonary absorption would have been much greater. Still in the cases formerly mentioned (§ 129), in which a large increase in weight could only be accounted-for on the supposition of absorption of water from the atmosphere, it seems probable that the cutaneous surface was chiefly concerned; for it can only be when the air introduced into the lungs is *saturated* with watery vapour, that the usual exhalation will be checked, or that any absorption can take place.

324. That absorption of other volatile matters diffused through the air, is, however, continually taking place by the lungs, is easily demonstrated. A familiar example is the effect of the inhalation of the vapour

* "Philosophical Magazine," vol. xxx. p. 478.
† "Casper's Wochenschrift," 1849, band 15.
‡ "Prize Essay on Cutaneous Absorption," p. 55.

of Turpentine upon the urinary excretion. It can only be in this manner that those gases act upon the system, which have a noxious or poisonous effect, when mingled in small quantities in the atmosphere; and it is most astonishing to witness the extraordinary increase in potency which many substances exhibit, when they are brought into relation with the blood in the gaseous form. The most remarkable example of this kind is afforded by Arseniuretted Hydrogen, the inspiration of a few hundredths of a grain of which has been productive of fatal consequences, the resulting symptoms being those of arsenical poisoning. Next to this, perhaps, in deleterious activity, is Sulphuretted Hydrogen; but it would seem that the effects of this gas upon the Human subject are scarcely so violent as they are upon animals; for though it has been found that the presence of 1-1500th part of it in the respired air will destroy a bird in a very short time, that 1-800th part suffices to kill a dog, and that 1-250th part is fatal to a horse, yet M. Parent-Duchatelet has affirmed that workmen habitually breathe with impunity an atmosphere containing *one per cent.*, and that he himself has respired, without serious symptoms ensuing, air which contained *three per cent.* There can be no doubt however, that the *continued* inhalation of air thus contaminated, would be speedily fatal. Sulphuretted hydrogen and Hydro-sulphuret of ammonia are given-off from most forms of decaying animal and vegetable matter; and it is undoubtedly to the accumulation of these gases, that the fatal results which sometimes ensue from entering sewers are to be chiefly attributed. Carburetted hydrogen is another gas whose effects are similar; but a larger proportion of it is required to destroy life.—Carbonic acid gas, also, appears to be absorbed by the lungs, when a large proportion of it is contained in the atmosphere. The accumulation of this gas in the blood, when the respired air is charged with it even to a moderate amount, might be attributed to the impediment thus offered to its ordinary exhalation (§ 313): but the following experiment appears to prove that it may be actually absorbed into the blood, and that it will thus exert a really-poisonous influence, and not merely produce an asphyxiating effect. It was found by Rolando, that the air tube of one lung of the land-tortoise may be tied, without apparently doing any material injury to the animal, as the respiration performed by the other is sufficient to maintain life for some time; but, having contrived to make a tortoise inhale carbonic acid by one lung, whilst it breathed air by the other, he found that the animal died in a few hours.*—Cyanogen is another gas which has an actively-poisonous influence upon animals, when absorbed into the lungs; its agency, also, is of a narcotic character.

325. It is singular that the effects of the respiration of pure Oxygen should not be dissimilar. At first, the rapidity of the pulse and the number of the respirations are increased, and the animal appears to suffer little or no inconvenience for an hour; but symptoms of coma then

* The fatal result of breathing the fumes of charcoal is, therefore, not simple Asphyxia, such as would result from breathing hydrogen or nitrogen.—Other volatile products are set free in the combustion of charcoal, besides carbonic acid. Mr Coathupe [illegible] states these to be Carbonate, Muriate, and Sulphate of Ammonia, Carbonic Oxide, Oxygen, Nitrogen, Watery vapour, and Empyreumatic Oil: to these, Sulphurous acid may appear to be properly added.

gradually develope themselves, and death ensues in six, ten, or twelve hours. If the animals be removed into the air before the insensibility is complete, they quickly recover. When the body is examined, the heart is seen beating strongly, while the diaphragm is motionless; the whole blood in the veins, as well as in the arteries, is of a bright scarlet colour, and several of the membranous surfaces have the same tint. The blood is observed to coagulate with remarkable rapidity, and it is to the alteration in its properties, occasioned by hyper arterialization (§ 180), and indicated by this condition, that we are probably to attribute the fatal result. There can be no doubt that in this instance, an undue amount of oxygen is absorbed; and it does not seem unlikely that one cause of the fatal result, is a stagnation of the blood in the systemic capillaries, consequent upon the want of sufficient change in its passage through them (§ 275).—When Nitrogen or Hydrogen is breathed for any length of time, death results from the deprivation of Oxygen, rather than from any deleterious influence which these gases themselves exert.—Death is also caused by the inhalation of several gases of an irritant character, such as Sulphurous, Nitrous, and Muriatic acids; but it is doubtful how far they are absorbed, or how far their injurious effects are due to the abnormal action which they excite in the lining membrane of the air-cells and tubes. It cannot be doubted, that Miasmata and other morbific agents diffused through the atmosphere, are more readily introduced into the system through the pulmonary surface than by any other; and our aim should therefore be directed to the discovery of some counteracting agents, which can be introduced in the same manner. The Pulmonary surface affords a most advantageous channel for the introduction of certain medicines that can be raised in vapour, when it is desired to affect the system with them speedily and powerfully; such is pre-eminently the case with those Anaesthetic agents, ether and chloroform, whose introduction into the various departments of Medical and Surgical practice constitutes a most important era in the history of the healing art; also with Mercury,* Iodine, Tobacco, Stramonium, &c.

3.—*Effects of Suspension or Deficiency of Respiration.*

326. We have now to consider the results of the cessation of the Respiratory function, and the consequent retention of Carbonic Acid in the blood. If this be sufficiently prolonged, a condition ensues, to which the name of *Asphyxia* has been given; the essential character of which is the cessation of muscular movement, and shortly afterwards of the Circulation; with an accumulation of blood in the venous system. The time which is necessary for life to be destroyed by Asphyxia varies much, not only in different animals, but in different states of the same. Thus, warm blooded animals are much sooner asphyxiated than Reptiles or Invertebrata; on the other hand, a hybernating Mammal supports life for many months, with a respiration sufficiently low to produce speedy asphyxia if it were in a state of activity. And among Mammalia and Birds, there are many species which are adapted, by peculiarities of con-

* The beneficial results of the introduction of Mercury by inhalation, are strikingly set forth in Mr Langston Parker's Essay on "The Treatment of Secondary, Constitutional, and Confirmed Syphilis."

formation, to sustain a deprivation of air for much more than the average period.* Excluding these, it may be stated as a general fact, that, if a warm-blooded animal in a state of activity be deprived of respiratory power, its muscular movements (with the exception of the contraction of the heart) will cease within five minutes, often within three; and that the circulation generally fails within ten minutes.—Many persons, however, are capable of sustaining a deprivation of air for two, three, or even four minutes,† without insensibility or any other injury; but this power, which seems possessed to the greatest degree by the divers of Ceylon, can only be acquired by habit. The period during which remedial means may be successful in restoring the activity of the vital and animal functions, is not, however, restricted to this. There is one well-authenticated case, in which recovery took place after a continuous submersion of fifteen minutes:‡ and many others are on record, of the revival of drowned persons after an interval of half an hour, or even more; but there is not the same certainty in regard to these, that the individuals may not have occasionally risen to the surface and taken breath there. It is not improbable, however, that in some of these cases a state of Syncope had come-on at the moment of immersion, through the influence of fear or other mental emotion, concussion of the brain, &c.; so that, when the circulation was thus enfeebled, the deprivation of air would not have the same injurious effect, as when this function was in full activity The case would then closely resemble that of a hybernating animal; for in both instances the being might be said to live very slowly, and would therefore not require the usual amount of respiration. The condition of the still born infant is in some respects the same; and re-animation has been successfully attempted, when nearly half an hour had intervened between birth and the employment of resuscitating means, and when probably a

* Thus, the Cetacea contain far more blood in their vessels, than do any other Mammalia; and these vessels are so arranged, that both arteries and veins are in connection with large reservoirs or diverticula. The reservoirs belonging to the former are usually full but when the Whale remains long under water, the blood which they contain is gradually introduced into the circulation, and, after becoming venous, accumulates in the reservoirs connected with the venous system. By means of this provision, the Whale can remain under water for more than an hour.

† Dr. Hutchinson states that any man of ordinary 'vital capacity' can pass two minutes without breathing, if he first makes five or six forcible inspirations and expirations, so as to cleanse the lungs of the old air, and then fills his chest as completely as he can. "For the first 15 seconds, a giddiness will be experienced; but when this leaves us, we do not feel the slightest inconvenience for want of air." (See "Cyclop. of Anat. and Phys." vol. iv p. 1065.)

‡ The following are the facts of this case, as narrated by Marc ("Manuel d'Autopsie Cadaverique Medico-Legale," p. 165) on the authority of Prater. A woman convicted of infanticide was condemned to die by drowning. This punishment was formerly inflicted in Germany according to the now obsolete Caroline law, the culprit being inclosed in a sack with a cock and a cat, and sunk to the bottom of the water. In this instance, the woman, after having been submerged for a quarter of an hour, was drawn up, and *spontaneously* recovered her senses. She stated that she had become insensible at the moment of her submersion; a circumstance which adds considerable weight to the supposition, based upon the post-mortem appearances in many cases of drowning, that death often takes place as much by Syncope (or primary failure of the heart's action, consequent upon sudden and violent emotion, or upon physical shock) as by Asphyxia. If the reality of this state of Syncopal Asphyxia be admitted, there does not seem any adequate reason for limiting the possible persistence of vitality in a submerged body, even to half an hour, especially if the temperature of the water be such as not to cause any rapid abstraction of its heat

much longer time had elapsed from the period of the suspension of the circulation.

327. It has now been sufficiently proved, both by experiment and by pathological observation, that the first effect of the non-arterialization of the blood in the lungs, is the retardation of the fluid in their capillaries; of which the accumulation in the venous system, and the deficient supply to the arterial, are the necessary consequences. It is some time, however, before a complete stagnation takes place from this cause; since, as long as the proportion of oxygen which remains in the air in the lungs is considerable, and that of the carbonic acid is small, so long will some imperfectly arterialized blood find its way back to the heart, and be transmitted to the system. This blood exerts a depressing influence upon the nervous centres, which is aided by the diminution that gradually takes place in the quantity of blood propelled to them; and thus the powers of the Sensorial centres are suspended, so that the individual becomes unconscious of external impressions; whilst the activity of the Medulla Oblongata also becomes diminished, so that the respiratory movements are enfeebled. The progressive exhaustion of the oxygen of the air in the lungs, and the accumulation of carbonic acid in the blood, increase the obstruction in the pulmonary capillaries; less and less blood is delivered to the systemic arteries, and what is thus transmitted becomes more and more venous; the nervous centres are now completely paralyzed, and the respiratory movements cease; and the deficient supply of blood, with the depravation of its quality, act injuriously upon the muscular system also, and especially weaken the contractility of the heart. In this enfeebled state, the final cessation of its movements seems attributable to two distinct causes, acting on the two sides respectively; for on the right side it is the result of the over-distension of the walls of the ventricle, owing to the accumulation of venous blood; and on the left to deficiency of the stimulus necessary to excite the movement, which is no longer sustained by its spontaneous motility (§ 242). The heart's contractility is not finally lost, however, nearly as soon as its movements cease; for the action of the right ventricle may be renewed, for some time after it has stopped, by withdrawing a portion of its contents,—either through the pulmonary artery, their natural channel,—or, more directly, by an opening made in its own parietes, in the auricle, or in the jugular vein (§ 247). On the other hand, the left ventricle may be again set in action, by renewing its appropriate stimulus of arterial blood. Hence, if the stoppage of the circulation have not been of too long continuance, it may be renewed by artificial respiration; for the replacement of the carbonic acid by oxygen in the air-cells of the lungs, restores the circulation through the pulmonary capillaries; and thus at the same time relieves the distension of the right ventricle, and conveys to the left the due stimulus to its actions.—Of the mode in which the Pulmonary circulation is thus stagnated by the want of oxygen, and renewed by its ingress into the lungs, no other consistent explanation can be given, than that which is based on the doctrine already laid-down in regard to the capillary circulation in general (§ 275), namely that the performance of the normal reaction between the blood and the surrounding medium (whether this be air, water, or solid organized tissue) is a condition necessary to the regular movement of the blood through the extreme vessels. That no

mechanical impediment to its passage is created (as some have maintained) by the want of distension of the lungs, has been fully proved by the experiments of Dr. J. Reid on the induction of Asphyxia by the respiration of azote. And that a contraction of the small arteries and capillaries, under the stimulus of venous blood, cannot be legitimately assigned as the cause of the obstruction, is evident from the consideration brought to bear upon it by the same excellent experimenter; namely, the *suddenness* with which the flow is renewed on the admission of oxygen, as contrasted with the *slowness* with which arteries dilate after the removal of the cause of their contraction (§ 256).*

328. It cannot be necessary here to dwell upon the fact, that by the repeated passage of the same air through the lungs, it may, though originally pure and wholesome, be so strongly impregnated with carbonic acid, and may lose so much of its oxygen, as to be rendered utterly unfit for the continued maintenance of the aerating process; so that the individual who continues to respire it, shortly becomes asphyxiated. There are several well-known cases, in which the speedy death of a number of persons confined together, has resulted from neglect of the most ordinary precautions for supplying them with air. That of the "Black Hole of Calcutta," which occurred in 1756, has acquired an unenviable pre-eminence, owing to the very large proportion of the prisoners, —123 out of 146,— who died during *one night's* confinement in a room 18 feet square, only provided with two small windows; and it is a remarkable confirmation of the views formerly stated (§ 226), and presently to be again adverted-to, that of the 23 who were found alive in the morning, many were subsequently cut-off by 'putrid fever.' Such catastrophes have occurred even in this country, from time to time, though usually upon a smaller scale; there has happened one at no distant date, however, which rivalled it in magnitude. On the night of the first of December, 1848, the deck-passengers on board the Irish steamer Londonderry were ordered below by the Captain, on account of the stormy character of the weather, and although they were crowded into a cabin far too small for their accommodation, the hatches were closed down upon them. The consequence of this was, that out of 150 individuals, no fewer than 70 were suffocated before the morning.

329. It cannot be too strongly impressed upon the Medical practitioner, however, and through him upon the Public in general, that the continued respiration of an atmosphere charged in a far inferior degree with the exhalations from the Lungs and Skin, is among the most potent of all the 'predisposing causes' of disease, and especially of those *zymotic* diseases whose propagation seems to depend upon the presence of fermentible matter in the blood. That such is really the fact, will appear from evidence to be presently referred-to; and it is not difficult to find a complete and satisfactory explanation of it. For, as the presence of even a small per-centage of carbonic acid in the respired air, is sufficient

* For a fuller discussion of the pathology of Asphyxia, see the "Cyclop. of Anat. and Phys.," art. 'Asphyxia,' by Prof. Alison, the "Library of Practical Medicine," vol. iii., art. 'Asphyxia,' by the Author, the Experimental Essay by Dr. J. Reid, 'On the Order of Succession in which the Vital Actions are arrested in Asphyxia,' in the "Edinb. Med. and Surg. Journ.," 1841, and in his "Anat., Physiol., and Pathol. Researches," and the Experimental Inquiry by Mr. Erichsen, in the "Edinb. Med. and Surg. Journ.," 1845.

to cause a serious diminution in the amount of carbonic acid thrown-off and of oxygen absorbed (§ 313), it follows that those oxidating processes which minister to the elimination of effete matter from the system, must be imperfectly performed, and that an accumulation of substances tending to putrescence must take place in the blood. Hence there will probably be a considerable increase in the amount of such matters in the pulmonary and cutaneous exhalation; and the unrenewed air will become charged, not only with carbonic acid, but also with organic matter in a state of decomposition, and will thus favour the accumulation of both these morbific substances in the blood, instead of effecting that constant and complete removal of them, which it is one of the chief ends of the respiratory process to accomplish. It has been customary to consider the consequences of imperfect respiration, as being exerted merely in promoting an accumulation of carbonic acid in the system, and in thus depressing the vital powers, and rendering it prone to the attacks of disease. But the deficiency of oxygenation, and the consequent increase of putrescent matter in the body, must be admitted as at least a concurrent agency; and when it is borne in mind that the atmosphere in which a number of persons have been confined for some time, becomes actually offensive to the smell in consequence of the accumulation of such exhalations, and that (as will presently appear) this accumulation exerts precisely the same influence upon the spread of zymotic disease, as that which is afforded by the diffusion of a sewer-atmosphere through the respired air, it scarcely admits of reasonable doubt, that the pernicious effect of over-crowding is exerted yet more through its tendency to promote putrescence in the system, than through the obstruction it creates to the due elimination of carbonic acid from the blood. For it is to be remembered, that whilst the *complete* oxidation of the effete matters will carry them off by the lungs in the form of carbonic acid and water, leaving urea and other highly-azotized products to pass-off by the kidneys, an *imperfect* oxidation will only convert them into those peculiarly offensive products which characterize the fæcal excretion (§ 118).*

330. Of the remarkable tendency of the Respiration of an atmosphere charged with the emanations of the Human body, to favour the spread of Zymotic diseases, a few characteristic examples will now be given.—All those who have had the widest opportunities of studying the conditions which predispose to the invasion of Cholera, are agreed that *over-crowding* is among the most potent of these; and from the numerous cases in which this was most evident, contained in the "Report of the General Board of Health" on the epidemic of 1848–9, the two following may be selected.—In the autumn of 1849, a sudden and violent outbreak of Cholera occurred in the Workhouse of the town of Taunton; no case of cholera having either previously existed, or subsequently presenting

* It is a remarkable confirmation of Prof. Liebig's analogy between the imperfect oxidation of effete matters within the body, and that combustion in a lamp or furnace insufficiently supplied with air which causes a deposit of soot and various empyreumatic products, that a set of acids have been found by Stadeler in the urine of the cow, bearing a remarkable analogy to well known products of destructive distillation, and one of them actually identical with the *carbolic acid* previously known as one of the ingredients of smoke.—See Prof. Gregory's "Handbook of Organic Chemistry," p. 450

itself, among the inhabitants of the town in general, although diarrhœa was prevalent to a considerable extent. The building was altogether badly constructed, and the ventilation deficient; but this was especially the case with the school-rooms, there being only about 68 cubic feet of air for each girl, and even less for the boys. On Nov 3, one of the inmates was attacked with the disease; in ten minutes from the time of the seizure, the sufferer passed into a state of hopeless collapse, within the space of forty-eight hours from the first attack, [illegible] cases and 19 deaths took place; and in the course of one week, 60 of the inmates, or nearly 22 per cent. of the entire number, were carried off, while almost every one of the survivors suffered more or less severely from cholera or diarrhœa. Among the fatal cases were those of 25 girls and 9 boys; and the comparative immunity of the latter, notwithstanding the yet more limited dimensions of their school-room, affords a remarkable confirmation of the general doctrine here advanced; for we learn that, although "good and obedient in other respects, they could not be kept from breaking the windows," so that many of them probably owed their lives to the better ventilation thus established. Now in the Gaol of the same town, in which every prisoner is allowed from 819 to [illegible] cubic feet of air, and this is continually being renewed by an efficient system of ventilation, there was not the slightest indication of the epidemic influence (Op. cit., pp. 37 and 71).—The other case to be here cited, is that of Millbank Prison, in which the good effects of the diminution of previous overcrowding were extremely marked. In the month of July, 1849, when the epidemic was becoming general and severe in the Metropolis (especially in those low ill-drained parts on both sides of the river, in the midst of which this prison is situated), the number of male prisoners was reduced, by the transfer of a large proportion of them to Shorncliff barracks, from 1039 to 402; the number of *female* prisoners, on the other hand, not only underwent no reduction, but was augmented from 120 to 131. Now the Cholera-mortality of London generally, which was 0·9 per 1000 in June and July, *increased* to 4·5 per 1000 in August and September; and the mortality among the *female* prisoners underwent a similar *increase*, from 8·3 to 53·4 per 1000; but the mortality among the *male* prisoners exhibited the extraordinary *diminution*, from 23·1 per 1000, which was its rate during June and July when the prison was crowded, to 9·9 per 1000, which was its rate during August and September after the reduction had taken place (Op. cit., App. B., p. [illegible]). It is scarcely possible to imagine a more *probative* case than this; since it shows, in the first place, the marked influence of the crowded state of the prison upon the fatality of the disease,—secondly, the diminution of mortality among the male prisoners, consequent upon the relief of the overcrowding, notwithstanding the quintupling of the general mortality of the Metropolis during the same period,—and thirdly, the vast greater increase of mortality among the female prisoners, which proves that the diminution among the males could not be attributed to any recession of the epidemic influence from the locality.

331. The cholera-experience of the Indian army is fertile in examples of the same kind, whose peculiar character makes them even more remarkable. It is to be remembered that the normal amount of Respiration is much lower in a hot, than in a temperate climate (§§ 155, 3[illegible]

consequently, any deficiency of oxygenation will tend in a yet higher degree to promote the accumulation of putrescent matter in the system, and this especially when there has been any unusual source of 'waste,' such as that induced by excessive muscular exertion.—The circumstances attendant upon the outbreak of Cholera, in 1846, at Kurrachee in Scinde, in which *ten per cent.* of an army of 6380 men were carried-off, place the influence of these conditions in a very striking point of view. In order that the comparison may be fairly made, the data specified in the following Table will be taken only from European regiments, similar to each other in diet, clothing, regimen, habits, and every other conceivable particular, save such as will be mentioned:—

Designation.	Strength.	Deaths	Deaths per 1000	Exposure at Drill, &c	Provision for Respiration.	Previous exertion.
Officers' Ladies .	42	0	0	Nil	Good	Nil.
Officers . .	200	3	15	Ordinary	Mostly good	Nil or slight.
Horse Brigade .	135	5	37	Ordinary	Good	Moderate.
60th Rifles . .	980	75	76·5	Ordinary	Bad	Nil.
Artillery . . .	375	37	96·6	Ordinary	Good	Severe.
Bombay Fusiliers	764	83	108·6	Ordinary	Very bad	Nil
Soldiers' Wives .	159	23	144·6	Nil	Mostly very bad	Partly severe.
D[illegible] of 86th Regt.	—	..	166·6	Nil	Very bad	Very severe.
86th Regiment .	1091	238	218	Ordinary	Very bad	Very severe.
	3746	464	124			

Now most of the Officers, and all the Ladies, were quartered in well-ventilated apartments; and the only predisposing cause from which the former could be considered as liable to suffer, was the exposure, in common with the soldiers, to the burning heat during the hours of drill. Of the 9 officers attacked with cholera, of whom 3 died (only one of the fatal cases being an uncomplicated one), 4 belonged to the Bombay Fusiliers, and had been living (like their men) in tents. The Horse Brigade were lodged in good barracks, but had recently come off a march of 1000 miles; being mounted, however, they must have suffered comparatively little fatigue from this. The 60th Rifles were quartered in barracks, but the ventilation of these was very imperfect, and the men were much crowded. The battalions of Artillery were quartered in good barracks; but three out of the four had recently made the march of 1000 miles on foot. The Bombay Fusiliers were quartered in tents, whose accommodation was so limited, that 10 or 12 men were cooped-up in a space 14 feet square, with the thermometer ranging from 96° to 100°, and without any adequate provision for ventilation. The 86th Regiment was quartered in precisely the same manner; and had recently made the march of 1000 miles under very unfavourable circumstances, besides having previously suffered from the debilitating influence of severe service. The condition of the Soldiers' Wives as regards their accommodation would be the same as that of their husbands, but they would not be subjected to the fatigue and exposure of drill; on the other hand, their fatigue and exposure during a march would be scarcely inferior to that of the men; and it was among the women, as among the soldiers, of the

86th Regiment, that the chief mortality occurred, their loss having been 1 in 6, or 166.6 per 1000. Thus we see that the *highest* rate of mortality presents itself, where the three causes were in concurrent action; the *absence* of mortality, where neither of them was in operation. The difference between the mortality of the Bombay Fusiliers (108.6 per 1000) and that of the 86th Regiment (218 per 1000), which were under precisely the same conditions as regards exposure and ventilation, shows the extraordinary influence of previous exertion; but that this would not of itself account for the high rate of mortality in the 86th, is shown by the smaller proportion of deaths in the Artillery; the influence of the same march upon three out of its four battalions, having been in a great degree kept-down by the adequate provision for their respiration; so that their mortality was less than that of the Bombay Fusiliers, who had not suffered from previous exertion, but were over-crowded in ill-ventilated tents.—It is scarcely possible to imagine any more satisfactory proof of the *preventibility* of a large part of this terrible mortality, than is afforded by the analysis of this case;* but if any confirmation be required, it is afforded by the case of Bellary, a fortress about 250 miles north-west of Madras. Although by no means unhealthily situated, this station was not free from Cholera for a single year between 1818 and 1844; and violent outbreaks took place occasionally, such as that of 1833, in which the 39th Regiment was reduced in five months from 735 men to 645, the number of deaths being 90, or 122½ per 1000. The barrack-accommodation in this fort was extremely insufficient for the garrison regularly quartered in it; yet small as it was, it was occasionally encroached-upon still further by the introduction of troops upon their march; and after such occasions of special overcrowding, a large increase in the mortality almost invariably occurred. But since the barrack-accommodation has been improved, the troops quartered at Bellary have ceased to suffer from cholera in any exceptional degree, and the ordinary rate of mortality has been considerably diminished.

332. The only condition of atmosphere which can be compared with that arising from overcrowding, in its effect upon the spread of Cholera, is that produced by the diffusion of the effluvia of drains, sewers, slaughter houses, manure-manufactories, &c., which correspond closely in their nature and effects with the putrescent emanations from the living human body. So remarkably has the localization of the disease shown itself to be connected with this condition, that the knowledge of the existence of the latter makes it safe to predict the former; such a prediction being scarcely ever falsified by the result. As a characteristic illustration of the operation of this cause, the outbreak of Cholera at Albert Terrace, Wandsworth road, in 1849, may be specially referred-to. The place consisted of 17 houses, having the appearance of commodious middle-class dwellings; the population does not seem to have averaged more than 7 individuals per house, so that there was no overcrowding; yet out of the total 119 or 120, no fewer than 42 persons were attacked with cholera, of whom 30 (or 25 per cent.) died. It was not difficult to account for this fearful result, when the circumstances of the case were inquired-into. About 200 yards in the rear of the terrace was an open

* For a fuller statement of it, see the "Brit. and For. Med.-Chir. Rev.," vol. ii. pp. 81-82

sewer, whose effluvia were most offensive at the backs of these houses, whenever the wind wafted them in that direction; and the drainage of the houses themselves was so bad, that a stench was continually perceived to arise from different parts of the kitchen floor, and more especially from the back kitchen. Moreover, in the house in which the first case of cholera occurred, there was an enormous accumulation of most offensive rubbish, exhaling a putrid effluvium. And there was also reason to believe, that the water supplied to some of the houses had accidentally become contaminated with the contents of a sewer and cesspool.*—The accumulation of night-soil and other rubbish in a triangular space of about three acres in Witham, a suburb of Hull, had been represented to the local authorities as almost certain to induce a severe outbreak of cholera in the neighbourhood, the prediction was disregarded; but it was most fearfully verified by the occurrence of no fewer than 91 deaths in its immediate neighbourhood.† Numerous examples of the same kind might be cited; but the following shows the efficacy of preventive measures. The Coldbath-fields House of Correction, situated in the neighbourhood of some of the most overcrowded and ill-drained parts of the metropolis, had suffered severely from Cholera in the epidemic of 1832-3; for out of 1148 prisoners, 207 were attacked with cholera, of whom 45 died, and 319 more suffered from diarrhœa. At that period, however, it was discovered that the whole drainage of the prison was in a most defective state, and steps were taken to have it completely and effectually renewed; at the same time the diet was somewhat improved, and more attention was paid to temperature and ventilation. In the epidemic of 1848-9, with 1100 prisoners, there was not a single case of cholera in this prison, although the disease was raging in its vicinity; and the cases of diarrhœa were few in number, and were mild in their character.‡

333. The Cholera-experience of the United States, during the Epidemic of 1849-50,§ afforded some of the most striking examples that have been anywhere displayed, both of the dire effects of neglect, and of the complete efficacy of preventive measures. The contrast is well shown in the manner in which the epidemic affected the town of Louisville, in Kentucky; which is situated by the Ohio river, on a plateau about 70 feet above low water mark, composed of sand and river-gravel, intermingled with tenacious clay, and reposing on a friable shale. This compound is peculiarly tenacious of moisture; and large ponds formerly existed, in the midst of which the first houses were built. While this state of things continued, Louisville was one of the most sickly towns in the Mississippi valley, and was commonly termed "the graveyard of the West." Intermittent fever was a regular visitant, and epidemics of fever of other types frequently raged with great severity. Thus, in the summer of 1822, after a hot rainy season, 232 persons died of bilious fever, out of a population of about 5000; in a family consisting of 20

* "Report of the General Board of Health on the Epidemic Cholera of 1848-9," p. 43.
† Op. cit., p. 45.
‡ Op. cit. App. B, p. 68.
§ See the "Abstract of Report by James Wynne, M.D., on Epidemic Cholera, as it prevailed in the United States in 1849 and 1850", constituting "Appendix C to the Report of the General Board of Health on the Epidemic Cholera of 1848-9."

persons, 19 were sick at one time, and in some families every individual died. At this period, only one street in Louisville was paved; and within its limits were at least eight ponds of greater or less dimensions, most of which, in the course of the autumn, were dried-up, exposing foul bottoms to the sun. Previously to the Cholera-epidemic of 1832-3, its condition had been somewhat improved; still the principal part of the town suffered severely. Much more, however, has been subsequently effected; so that from being reputed one of the most unhealthy towns in the west, Louisville has come to be esteemed one of the most healthy: at the same time its population has increased from 10,000 in 1830, to 50,000 in 1850. Entire squares are now pointed-out, which occupy the beds of ponds once large and deep enough to float a steamboat. Still much of the lower part of the city is in a very foul condition; the ground on which it is built being saturated with water to a considerable depth after heavy rains, and being also the receptacle of the filthy washings of the more elevated portion; besides having many nuisances of its own, especially accumulations of decaying hemp-offal. It was in this part that Cholera first made its appearance in 1849, in the identical square in which the earliest cases had appeared in 1832; and to this part it was almost entirely restricted. "*Those places in Louisville*," says the Medical Reporter, "*which bore the brunt of the Cholera in* 1833, *and which have been improved so as to be dry, clean, and airy, have been as free from Cholera as from the oriental plague. But those places in this city which were scourged in* 1833, *and which remain now in the state they were in then, have been scourged again in* 1849-50."

334. A yet more remarkable contrast is presented by the comparative experience of the City and of the Almshouse of Baltimore. During the spring of 1849, when, from the prevalence of Cholera in the great towns to the north, it appeared next to certain that the epidemic would visit Baltimore, not only its public authorities, but its citizens generally, exerted themselves with commendable zeal to ward-off its severity by active measures of sanitary purification. Although in many respects superior to the average of large towns, Baltimore was by no means free from those collections of filth invariably found to a greater or less extent among the most degraded portion of their population, and of the evil results of these, the constant presence of typhoid fever, among the miserable coloured inhabitants of its worst localities, had long furnished a standing proof. During the summer months, when the city was completely surrounded by the Choleraic atmosphere, diarrhœa and kindred affections became very prevalent in Baltimore; and Dr Wynne further mentions, as of universal occurrence in those who had not a positive attack of diarrhœa, "an undefinable sense of oppression, not amounting to pain, over the whole region of the abdomen, reminding the person constantly of the existence of such a part of the body." This state of things impressed the Medical authorities with the belief that the Cholera-poison was brooding over the town, and that an outbreak might be continually expected. Yet it entirely passed away, without giving rise to more than *four* attacks of genuine Cholera; two of these being in the persons of Germans, who occupied a wretched tenement in a very filthy condition; the third case being that of a man, whose sleeping apartment looked-out upon an alley which had been suffered to

remain in a very foul state; whilst the fourth, which occurred in the largest and most fashionable hotel in the city, was obviously an imported case.—Yet, as if for the very purpose of demonstrating that the immunity which the City itself enjoyed, was entirely due to the sanitary precautions which its inhabitants had so wisely taken, a fearful outbreak of Cholera took place in the Almshouse, only two miles out of town, which proved fatal to 99 persons out of a population of 632, or *nearly one in six*, and it was only kept within this limit, by the promptness with which the sources of this terrible mortality were removed, when once they had been discovered.

335. The circumstances of this outbreak were so peculiar, as to need a somewhat detailed description.—The main building of the Almshouse was originally the country-seat of a wealthy citizen, who erected a costly mansion on an elevated site which he had specially chosen for its beauty and healthfulness; it had subsequently been much enlarged, for the accommodation of its six or seven hundred inmates; but it still remained entirely isolated, being surrounded by a farm of 200 acres, for the most part devoted to cultivation. From the original centre, two principal wings extended on either side, one for the male and the other for the female side, forming an extensive range of building, whose front had a southern aspect, whilst the back looked towards the north. Behind this were other wings running north and south, with various offices, spread over an area of about 4½ acres, which was enclosed by a wall. Like the city itself, the Almshouse had received a thorough purification, under the superintendence of the visiting physician; whose directions, as regarded ventilation and internal cleanliness, seem to have been strictly complied with. Nevertheless an unequivocal case of Cholera presented itself on July 1st, another on July 7th, four more during the ensuing week, and on July 14th *thirteen* of the inmates were attacked at once. All the patients were old inhabitants of the establishment, and had unequivocally contracted the disease on the spot; but although fully impressed with the conviction that some special cause must exist for this rapidly-increasing mortality, the visiting physician did not succeed in detecting it until the 19th, when he extended his survey, for the first time, beyond the enclosure. He then discovered that the whole triangular space included between its posterior boundary-wall, and a ravine which approached within nine feet of its western angle, but which was separated from its eastern angle by an interval of about seventy feet, was *one putrid and pestilential mass*, capable of generating, under the ardent rays of a mid-summer sun, the most poisonous emanations; for although the ravine was admirably adapted to carry-off the drainage of the establishment, this had never been properly conducted into it; the overflowings of cesspools, pigsties, &c., having been allowed to spread themselves over the intervening area, which they kept, of course, in a state of constant pollution, superficially concealed by a rank weedy vegetation. Some difficulty was experienced in procuring men to remove this nuisance, so that it remained untouched till the 23rd. The pools of filth were then drained by trenches into the ravine, and were washed out by a stream of fresh water; lime was spread over the whole surface; and this again was covered with a thick layer of earth. The men employed in this work were attacked with Cholera, but recovered. *The day after it was*

completed, the number of cases in the Almshouse suddenly dropped from *eleven* to *three*, and within a fortnight more, the disease had entirely disappeared.—But this is by no means all. The attacks of Cholera were far from being uniformly distributed through the building, but were almost exclusively restricted to those parts of it which were directly exposed to the emanations conveyed from this pestilential spot, by the northerly wind which blew steadily during the whole time of the prevalence of the disease. Thus, in the centre building, the Manager who slept in a room looking to the *north*, was attacked, but recovered; among his family, whose rooms looked to the *south*, no case of the disease occurred. Four medical students who occupied rooms beneath that of the Manager, and with the same exposure, were attacked, but recovered; four others, lodged in similar rooms with a southern exposure, entirely escaped. The Apothecary and coach-driver, who occupied rooms in the men's wing with windows opening to the north, were both attacked but both recovered. Among the pauper inmates of the wings, those generally were seized who slept in the northern wards; and it was observable that the male side suffered generally much more severely than the female; a difference not attributable to anything in the building or its inhabitants, but at once explained by the fact, that whilst no barrier existed between the male side and the putrid marsh, the female wing was protected from the pestilential current by three intervening rows of trees.* On the female side, however, a building ran in a north and south direction, of which the lower storey had a door in the north, opening quite near the putrid marsh, whilst the upper storeys had only a blank wall at this end; this lower storey was tenanted by *seventeen lunatics, all of whom were attacked with Cholera, and all died*, whilst not a single attack of Cholera took place among the inmates of its upper storeys. And in addition, it was noticed that the removal of the Cholera patients to the ward above the black people's hospital, where the miasmatic influence was entirely unobstructed, was attended with a marked aggravation of their malady.

336. Now although the Cholera-epidemics have been here referred to, as affording the most remarkable examples of the influence of a contaminated atmosphere in predisposing the individuals habitually living in it to the invasion of Zymotic disease, yet the evidence is not less strong in regard to the uniform prevalence of ordinary Fevers, &c., in the same localities; the places in which Cholera was the most severe, having been almost invariably known as 'fever-nests' in other periods, and being distinguished by a very high rate of mortality. Thus the average age of all persons who die in Witham, is only 18 years; whilst the average age at death in the town of Hull (itself distinguished by an unusual brevity of life) is 23 years. In the 'Potteries' at Kensington, a locality in which filth and overcrowding prevail to an almost unequalled degree, the mortality for three years previously to the invasion of cholera had been such

* These probably acted not merely mechanically, by obstructing the current, but also chemically by decomposing or oxidating the noxious emanations. For it has been frequently remarked, that a screen or belt of umbrageous trees effectually secures the dwellers on the borders, and even on the leeward side, of the most pestiferous marshes, from the effects of their malaria. How far they have the same influence on *animal* effluvia, we are not yet in a position to state.

that the average age at death was only 11 yrs. 7 mo.; and in the *first ten months* of 1849, out of a population of about 1000, there were 50 deaths, of which 21 were from cholera and diarrhœa, and 29 from typhus fever and other diseases. It is illustrative of the common points between cholera and other zymotic diseases, that the former appeared there not only in the same streets and in the same houses, but even in the same rooms, which had been again and again visited by typhus; and there were several tenants of such rooms, who only recovered from fever in the spring, to fall victims to cholera in the summer. Subsequently to this epidemic, the average age at death has been further reduced, by an increase of infantile mortality, to as low as 10 years.—By way of contrast, it may be stated that in one of the "Model Lodging-Houses," containing about 550 inmates, among whom was an unusually large proportion of children, the rate of mortality during the three years ending May, 1851 (including the whole period of the cholera-epidemic), was scarcely more than 20 in 1000; the proportion of deaths under ten years of age was only half that of the metropolis in general; there was not a single attack of cholera, and there were only a few cases of choleraic diarrhœa, although the disease was raging in the immediate vicinity; and from the time that the sewerage had been put into complete order, typhus fever had entirely disappeared, a few cases having occurred soon after the opening of the buildings, which were distinctly traceable to a defect in the drainage.* —The following case may be added, in proof of the potency of an atmosphere charged with putrescent emanations, in rendering the system liable to the attacks of Zymotic diseases of various kinds. A manufactory of artificial manure formerly existed immediately opposite Christchurch workhouse, Spitalfields, which building was occupied by about 400 children, with a few adult paupers. Whenever the works were actively carried-on, particularly when the wind blew in the direction of the house, there were produced numerous cases of fever, of an intractable and typhoid form; a typhoid tendency was also observable in measles, small-pox, and other infantile diseases, and for some time there prevailed a most unmanageable and fatal form of aphthæ of the mouth, ending in gangrene. From this last cause alone, 12 deaths took place among the infants in three months. In the month of December, 1848, when cholera had already occurred in the neighbourhood, 60 of the children in the workhouse were suddenly seized with violent diarrhœa in the early morning. The proprietor was compelled to close his establishment, and the children returned to their ordinary health. Five months afterwards, the works were recommenced; in a day or two subsequently, the wind blowing from the manufactory, a most powerful stench pervaded the building. In the night following, 45 of the boys, whose dormitories directly faced the manufactory, were again suddenly seized with severe diarrhœa; whilst the girls, whose dormitories were in a more distant part, and faced in another direction, escaped. The manufactory having been again suppressed, there was no subsequent return of diarrhœa.†

337. It may not be amiss to add a few examples drawn from the

* "Op. cit.," App. B, pp. 48 and 77; and Mr. Grainger's subsequent "Report on the present state of certain parts of the Metropolis, and on the Model Lodging-Houses of London," pp. 29–36.

† "Report of the Board of Health on Cholera, 1848-9," p. 42.

experience which our Indian possessions have afforded, of the influence of an insufficient supply of pure air upon the *ordinary mortality* in our army and among the people under our control.—There are various military stations, which have lain under a most ill-deserved repute for unhealthiness, in consequence of the very imperfect barrack-accommodation afforded to the troops quartered in them. Thus at Secunderabad, in the Madras command, the average annual mortality for the fifteen years previous to 1846-7, was 75 per 1000; this being *nearly double* the average of the whole presidency, and *more than double* that of the remainder of the stations. Now the complaints made year after year by the medical officers of the troops which have been successively quartered at this station, leave no room for doubt as to the chief cause of this excess; for the regiments of the Line quartered at Secunderabad have been always crowded in barracks quite insufficient for their accommodation, one-third of the men having been obliged to sleep in the verandahs, and the remainder getting by no means a due allowance of fresh air; whilst, on the other hand, the Officers of these very regiments, who are better accommodated, and the detachment of Artillery quartered in more roomy barracks at no great distance, have never participated in this unusual mortality, thereby clearly showing the absence of any special causes of disease at this station, which might not be easily removed.* The Barrackpore station, in the Bengal command, is even worse than the foregoing, for every regiment quartered there, seems to suffer an almost complete *decimation* annually. Yet there is ample evidence, that here also the chief fault lies in the barrack-accommodation. But one of the most terrible instances of the continuance of a high rate of mortality which is almost entirely attributable to an insufficient supply of air, is that which is furnished by the Gaols under British control in India. In these are usually confined no fewer than 40,000 prisoners, chiefly natives; and the average annual mortality of the whole was recently 10 per cent., rising in some cases to 26 per cent., or more than *one in four*. This is easily accounted-for, when it is known that in no case is there an allowance of more than 300 cubic feet of air-space for each individual, whilst in some instances 70 cubic feet is the miserable average!†

338. One more set of cases will be cited, as showing the marked effect of the habitual respiration of a contaminated atmosphere, not merely in engendering a liability to zymotic disease, but in directly producing a special form of infantile spasmodic disease, of the most fearful nature.—The dwellings of the great bulk of the population of Iceland seem as if constructed for the express purpose of poisoning the air which they contain. They are small and low, without any direct provision for ventila-

* It is a remarkable confirmation of the view formerly stated (§ 65), as to the tendency of the habitual use of Alcoholic liquors to induce a 'fermentible' condition of the blood, by obstructing the elimination of the effete matters by the respiratory process (§ [illegible]), that when the 84th Regt., which is distinguished for its sobriety, was quartered at Secunderabad in 1847-8, it lost only 39 men out of 1139, or 34.2 per 1000, the average mortality of the other stations in the Presidency being about the same as usual. On the other hand, the 63rd Regt., which was far from deserving a reputation for temperance, lost 73 men during the first nine months of the preceding year, or at the rate of [illegible] per [illegible] during the entire year.—All the facts here stated in regard to Secunderabad, have been obtained by the Author direct from the Army Medical Returns.

† Dr Mackinnon's "Treatise on the Public Health, &c., of Bengal," Cawnpore, 1848, chap. 1.

tion, the door serving alike as window and chimney; the walls and roof let-in the rain, which the floor, chiefly composed of hardened sheep-dung, sucks-up; the same room generally serves for all the uses of the whole family, and not only for the human part of it, but frequently also for the sheep, which are thus housed during the severer part of the winter. The fuel employed in the country districts chiefly consists of cow-dung and sheep-dung, caked and dried; and near the sea-coast, of the bones and refuse of fish and sea-fowl; producing a stench, which, to those unaccustomed to it, is completely insupportable. In addition to this, it may be mentioned that the people are noted for their extreme want of personal cleanliness; the same garments (chiefly of black flannel) being worn for months without being even taken-off at night. Such an assemblage of unfavourable conditions, combined with the cold damp nature of the climate, might have been expected to induce tubercular diseases of various kinds; but from these the Icelanders appear to enjoy a special exemption (§ 57 III). Syphilis, also, is wanting, or nearly so; and yet, notwithstanding that the number of births is fully equal to the usual average, the population is stationary, and in some parts actually diminishing. This is partly due to the extent and fatality of the epidemic diseases, of which some one or other spreads through the island nearly every year; but it is chiefly owing to the extraordinary mortality of infants from *Trismus nascentium*, which carries-off a large proportion of them between the fifth and the twelfth days after their birth. It is in the little island of Westmannoe and the opposite parts of the coast of Iceland, where the bird-fuel is used all the year round, instead of (as elsewhere) during a few months only, that this disease is most fatal; the average mortality for the last twenty years, during the first twelve days of infantile life, being no less than 64 per cent., or nearly *two out of three.**—Now it is not a little remarkable that the very same disease should have prevailed, under conditions almost identically the same, in the island of St. Kilda, one of the Western Hebrides; the state of which was made known by Mr. Maclean, who visited it in 1838. The population of this island, too, was diminishing rather than increasing, in consequence of the enormous infantile mortality; *four out of every five* dying, from Trismus nascentium, between the eighth and twelfth days of their existence. The great if not the only cause of this mortality, was the contamination of the atmosphere by the filth amidst which the people lived. Their huts, like those of the Icelanders, were small, low-roofed, and without windows; and were used during the winter as stores for the collection of manure, which was carefully laid out upon the floor, and trodden under foot to the depth of several feet. On the other hand, the clergyman, who lived exactly as did those around him, except as to the condition of his house, had brought-up a family of four children in perfect health; whereas, according to the average mortality around him, at least three out of the four would have been dead within the first fortnight.—Of the degree in which this fearful disease is dependent upon impurity of the atmosphere, and is preventible by adequate ventilation, abundant proof is afforded by the experience of Hospitals and Workhouses in our own country. Thus in the Dublin Lying-in Hospital, up to the year 1782, the mortality within the first fortnight, almost entirely from

* See "Island undersøgt fra lægevidenskabeligt Synspunct." Af P. A. Schleisner, M.D. Copenhagen, 1849.

Trismus nascentium, was 1 in every 6 children born. The adoption, under the direction of Dr. Joseph Clarke, of an improved system of ventilation, reduced the proportion of deaths from this cause to 1 in 19½. And further improvements in ventilation, with increased attention to cleanliness, during the seven years in which Dr. Collins was Master of this Institution, reduced the number of deaths from this disease to no more than three or four yearly.*—A similar amelioration took place about a century ago, in the condition of the London Workhouses, in which 23 out of 24 infants had previously died within the first year, and a large proportion of these within the first month; for owing to a parliamentary inquiry which was called-forth by this fearful state of things, the proportion of deaths was speedily reduced (chiefly by improvement in ventilation) from 2600 to 450 annually.

339. Thus it appears that in all climates, and under all conditions of life, the *purity of the atmosphere* habitually respired is essential to the maintenance of that power of resisting disease, which, even more than the ordinary state of health, is a measure of the real vigour of the system. For, owing to the extraordinary capability which the human body possesses of accommodating itself to circumstances, it not unfrequently happens that individuals continue for years to breathe a most unwholesome atmosphere, without apparently suffering from it; and thus, when they at last succumb to some Epidemic disease, their death is attributed solely to the latter; the previous preparation of their bodies for the reception and development of the zymotic poison, being altogether overlooked. It is impossible, however, for any one who carefully examines the evidence, to hesitate for a moment in the conclusion, that the fatality of Epidemics is almost invariably in precise proportion to the degree in which an impure atmosphere has been habitually respired; that an atmosphere loaded with putrescent miasmata may afford a *nidus* wherein a zymotic poison undergoes a marked increase in quantity and intensity, the putrescent exhalations from the lungs and skin of the living subject being at least as effectual in furnishing such a 'nidus,' as are the emanations from fæcal discharges or from other decomposing matters; that the habitual respiration of such an atmosphere tends to induce a condition of the blood which renders it peculiarly susceptible of perversion by the introduction of zymotic poisons, and which favours their multiplication within the system;† and lastly, that by due attention to the various means of promoting atmospheric purity, and especially by efficient ventilation and sewerage, the rate of mortality may be enormously decreased, the amount and severity of sickness lowered in at least an equal proportion, and the fatality of epidemics almost completely annihilated. And it cannot be too strongly borne in mind, that the efficacy of such *preventive* measures has been most fully substantiated, in regard to many of the very diseases

* See Dr. Collins's "Practical Treatise on Midwifery," p. 513.

† A careful consideration of the very satisfactory evidence which has been of late years collected on this point, must (in the Author's opinion) satisfy any *competent* and *unprejudiced* inquirer, that Endemic Fevers, originating in local causes (marsh miasmata and the like), and at first affecting those only who are exposed to such causes, may find, by the crowding together of infected subjects, a *nidus* for development within the Human system; so that these diseases *then* become communicable by human intercourse, although not so originally.—For a discussion of this subject, see the Articles on 'Yellow Fever' and the 'Fever of Boa Vista,' in the "Brit. and For. Med.-Chir. Rev.," vols. i. ii. and iv.

in which the *curative* power of Medical treatment has seemed most doubtful, as for example, in Cholera and Malignant Fevers.—The practical importance of this subject may be estimated from the startling fact, which enquiries prosecuted under the direction of the Board of Health have recently brought to light;*—viz., that the *difference* in the annual rates of mortality, between the most healthy and the most unhealthy localities in England, amounting to no less than 34 in 1000, is almost entirely due to Zymotic diseases, which might be nearly (if not completely) exterminated by well-devised sanitary arrangements. The *lowest* actual mortality is 11 per 1000, while the *highest* is 45 per 1000; and between these extremes, there is every intermediate degree of range. But what may be termed the *inevitable* mortality,—arising from diseases which would not be directly affected by Sanitary improvements—is a *nearly constant* quantity throughout; namely, the 11 per 1000 of those districts which are free from Zymotic disease. The average mortality of all England, in ordinary years, is about 22 per 1000, or just double that to which it might be reduced; so that, taking the population of England and Wales (as by the last Census) at nearly 18 millions, the average annual mortality must be 396,000, of which only 198,000 is *inevitable*, an equal amount being *preventible.*

CHAPTER VIII.

OF NUTRITION.

1.—*General Considerations.—Formative Power of Individual Parts.*

340. THE function of Nutrition, considered in the widest acceptation of the term, includes that whole series of operations, by which the alimentary materials,—prepared by the Digestive process, introduced into the system by Absorption, and carried into its *penetralia* by the Circulation,—are converted into Organized tissue: but in a more limited sense it may be understood as referring to the last of these operations only, that of *Histogenesis* or tissue-formation, to which all the other organic functions, in so far as they are concerned in maintaining the life of the individual, are subservient, by preparing and keeping in the requisite state of purity the materials at the expense of which it takes place. It is shown elsewhere (PRINC. OF GEN. PHYS.), that every integral part of the living body possesses a certain capacity for growth and development, in virtue of which it passes through a series of successive phases, under the influence of the steady Heat, which in the warm-blooded animal is constantly acting upon it; this capacity being an endowment which it derives by direct descent from the original germ (CHAP. XVI.), but undergoing a gradual diminution with the advance of life (CHAP. XVIII.), until the power of *maintenance* is no longer adequate to antagonize the forces that tend to the *disintegration* of the system. It has been also shown (CHAP. V.), that notwithstanding the diversities in the structure and composition of the several tissues, the Blood supplies the materials which

* See "Summary of Experience on Disease, and Comparative Rates of Mortality," by William Lee, Superintending Inspector, 1851.

each requires; every tissue possessing (so to speak) an *elective affinity* for some particular constituents of that fluid, in virtue of which it abstracts them from it, and appropriates them to its own uses.—But it has been shown, on the other hand, that the 'formative capacity' does not exist in the tissues alone, but is shared by the Blood, which must itself be regarded as deriving it from the original germ; for there are certain simple kinds of tissue, which appear to take their origin directly in its plastic components (§ 198). Of others, which cannot be said thus to originate in the blood, the development seems to be entirely determined by the quantity of their special *pabula* which it may contain. Thus, an increase of Adipose tissue takes place, when the blood habitually includes an unusual amount of fat; an augmentation in the proportion of the Red Corpuscles of the blood may be distinctly observed (especially if it has been previously diminished unduly), when an additional supply of iron is afforded (§ 1[illegible]); and when one of the Kidneys has been removed, or is prevented by disease from performing its normal function, the other, if it remain healthy, undergoes an extraordinary increase in size, so as to perform the duty of both organs, the augmented development of its secreting structure being here also fairly attributable to the accumulation of its appropriate materials in the blood.* Even of those tissues which must be considered as most independent and self-sustaining, the development is not only checked by the want of a due supply of their appropriate materials, but it is modified in a very remarkable degree by the presence of abnormal substances in the blood, which single-out particular parts, and effect determinate alterations in their nutrition, in such a constant manner as to show the existence of a peculiar 'elective affinity' between them (§ 217).—In so far, then, as the process of Nutrition is dependent upon the due supply and normal state of the Blood, its conditions have been already sufficiently discussed, and we have now only to consider it in its relations to the Tissues.

341. The demand for Nutrition primarily arises from the tendency of the organism to simple *Increase* or *Growth*. Of this we have the most characteristic illustration in the multiplication of the first embryonic cell, by the simple process of 'duplicative subdivision,' whereby a multitude of cells is produced, every one of which is similar in all essential particulars to the original. But after the different parts of this homogeneous embryonic mass have taken upon themselves their respective modes of development, so as to generate a diversity of tissues and organs,

* This principle is one most fertile in Pathological applications; for there can be little doubt that the development of many morbid growths is due, not so much to a perverted local action, as to the presence of certain morbid matters in the blood, which determine the formation of tissues that use them as their appropriate pabulum. Such is pretty obviously the case with those disorders, which (like the Exanthemata) are universally admitted to be of 'constitutional' character, and which are distinctly traceable to a poison introduced through the blood, whose first influence is exerted in modifying the physical and vital properties of that fluid; and the evidence has been of late accumulating that it is true also of the various forms of Cancer, the local development of an abnormal structure being in this case, also, nothing else than the manifestation of the existence of that peculiar matter in the blood, which is the appropriate nutriment of its component tissues (§ 231), or, as Mr Simon appropriately designates it, "a new excretory organ, which tends essentially to acts of eliminative secretion, just as distinctly as the healthy liver or the healthy kidney."—See Mr Simon's "Lectures on General Pathology," pp. 87, 152; and Mr Paget's "Lectures on Surgical Pathology," vol. i. p. 441, and vol. ii. pp. 528 et seq.

each one of these continues to increase after its own plan; and thus the child becomes the adult, with comparatively little change but that of growth (CHAP. XVI., Sect. 4). An excess of growth, taking place conformably to the normal plan of the tissue or organ, constitutes *Hypertrophy;* whilst a diminution, without degeneration or alteration of structure, is that which is properly distinguished as *Atrophy.*—But Growth is not confined to the period of increase of the body generally; for it may manifest itself in particular organs or tissues, as a normal operation, at any subsequent part of life; as when an extraordinary demand for the functional activity of a particular set of Muscles is supplied by an increase in the amount of their contractile tissue. —And further, even where there is no such manifestation of increase, there is really a continual growth in all the tissues actively concerned in the vital operations, and this even to the very end of life; although it may be so far counterbalanced, or even surpassed, by changes of an opposite kind (§ 22), that instead of augmentation in bulk, there is absolute diminution.

342. The evolution of the complete organism from its germ, however, does not consist in mere growth; for by such a process nothing would be produced but an enormous aggregation of simple cells, possessing little or no mutual dependence, like those which constitute the shapeless masses of the lowest Algæ (See PRINC. OF GEN. PHYS.) In addition to increase there must be *Development,* that is, a passage to a higher condition, both of form and structure; so that the part in which this change takes-place becomes fitted for some special function, and is advanced towards the state in which it exists in the highest or most completed form of its specific type. Thus the development of *tissue* consists in the change from a simple mass of cells or fibres into any other form; as in the production of Dentine from the cellular substance of the tooth-pulp, or in the formation of Bone in the sub-periosteal membrane. So, again, the developmental change is seen in the passage of an entire *organ* from a lower to a higher condition, by the evolution of new parts, or by a change in the relations of those already existing, even though the change in its texture should consist of little else than of simple increase: thus in the development of the Heart, we have the original single cavity subdivided, first into two, and at last into four chambers, and in the development of the Brain, we find the sensory ganglia to be the parts first formed, the anterior lobes of the cerebrum to be evolved (as it were) from these, the middle lobes sprouting-forth from the back of the anterior, and the posterior from the back of the middle; yet with all this, there is no production of any new kind of tissue, the new parts being generated at the expense of histological components identical with those of the pre-existing.—Now it is in the early period of embryonic life, that the *developmental* process is most remarkably displayed; for it is then that we see that transformation of the primordial cells into tissues of various kinds, which originates a special *nisus* in each part, whereby the production of the same tissue, in continuity with that first-formed, comes to be a simple act of growth; and it is then also that we observe that marking-out of all the principal organs, by the development of tissue in particular directions, which makes all subsequent evolution but a completion or filling up of the plan thus sketched-out. Thus, during the first days of incubation in

the Chick, the foundation is laid of the vertebral column, the nervous centres, the organs of sense, the heart and circulating system, the alimentary canal, the respiratory apparatus, the liver, the kidneys, and many other parts; and at the termination of that period, the chick emerges in such a state of completeness of development, that little else than increase is wanting, save in the plumage and sexual organs, to raise it to its perfect type. The same may be said of the Human organism; save that the period of its development is relatively longer, in accordance with the higher grade which it is ultimately to attain; its earliest stages being passed-through, however, with extraordinary rapidity. The completer evolution of the generative organs, of the osseous skeleton, and of the teeth, constitute the principal developmental changes which the Human organism undergoes in its progress from the infantile to the adult condition; almost every other alteration consisting in simple increase of its several component tissues and organs, without any essential change in their form or structure. And when the adult type has been once completely attained, every subsequent change is one rather of degeneration than of development, of retrogression rather than of advance.

343. The difference between these two processes of Growth and Development is most characteristically shown in those cases, in which there is a partial or complete arrest of one of them, without any corresponding impairment of the other. Thus a dwarf, however small in stature, may present a perfect development of every part that is characteristic of the complete human organism; the deficiency being solely in the capacity for *growth*. On the other hand, the usual size at birth may be attained, and every organ may present its ordinary dimensions, and yet some important part may be found in a condition of *arrested development*: thus the Heart may consist of a single cavity, or the inter-ventricular or inter-auricular septa may be incomplete, so that it has not passed beyond the grade of development which it had attained at an early period of embryonic life, although its growth may have continued; or the Brain may in like manner exhibit a deficiency of the posterior lobes, or of the corpus callosum, or of some other part whose formation normally takes place in the latter months of intra-uterine life, although the parts already produced may have continued to grow at their usual rate.—Numerous instances of the same kind might be cited, but these must suffice.

344. The demand for Nutrition arises, however, not merely from the exercise of the formative powers which are concerned in the building up of the organism, but also from the degeneration and decay which are continually taking-place in almost every part of it, and the effects of which, if not antagonized, would speedily show themselves in its complete disintegration. As each component cell of the organism has to a certain degree an independent life of its own, so has it also a limited duration; and its duration usually bears an inverse ratio to its functional activity (See PRINC. OF GEN. PHYS.) This is particularly striking, when we compare the ratio of change in the organisms of cold-blooded animals at low and at high temperatures; for they live slowly, need little nutriment, give-off but a small amount of excretory products, and require a long time for the performance of the reparative processes, under the former condition; but live fast, require a comparatively large supply of

nutriment, give-off a far greater amount of carbonic acid and other excretions, resulting from the 'waste' of tissue, and exhibit a far more rapid reparation of injuries, in the latter state. The constantly high temperature of Man, as of other warm-blooded animals, prevents this difference from being displayed in him in a similar manner; but it is well seen when we contrast his different tissues with each other, and study their respective histories. For whilst there are some (I.) which appear to pass through all their stages of growth, maturation, and decline, within a limited period, there are others (II.) whose existence seems capable of almost indefinite prolongation, and others (III.), again, which are liable to have a period put to their life at any time, by the direction of their vital force into other channels.

I. Of those belonging to the first category, which are actively concerned in the purely *vital* operations of the organism, a characteristic example is presented by the Ovule; which, if not fertilized within a limited period after its maturation, speedily declines and decays; and the same law of limited duration doubtless extends to a large proportion of such tissues as are actively concerned in the maintenance of the organic functions; as for example, the Corpuscles of the blood (§ 166), the Epithelial cells of many glands which are instrumental in the process of Secretion (§ 379), the cells forming the parenchyma of the Absorbent and Vascular Glands (§§ 131, 142 III.), and many others.

II. The contrary extreme to this may be found in those tissues, whose functions are rather *physical* than vital; and especially in such as undergo consolidation by the deposit of solidifying matter, either in combination with the animal membrane or fibre, or in its interstices. Such tissues are more withdrawn from the general current of vital action; and there seems to be no definite limit to the duration of some of them, except such as is imposed by the chemical and mechanical degradation to which they may be subjected. This appears to be the case with the simple Fibrous tissues, especially the yellow, even in their soft or unconsolidated state; but it is far more obvious in the dentine and enamel of Teeth, which are formed by the combination of calcareous salts with an animal matrix, and which retain their condition apparently unchanged through the whole remainder of life, under circumstances which show that if any nutritive action take place in them, its amount must be extremely small. In the dentinal structures of the young, however, there is obviously a determinate limit of existence; as is shown by the exuviation, at a certain definite epoch, of the first set of teeth, which exuviation is usually preceded by the death and partial disintegration of their texture. In Hair, Nails, and other Epidermic appendages, again, whose substance, when once it has undergone consolidation by the deposit of horny matter, may remain unchanged for centuries, we must recognise the same principle of indefinite duration, in connection with the cessation of vital activity; the chemical constitution of these textures, moreover, being such as renders them but little prone to be acted-upon by ordinary decomposing agencies. The limit of existence seems more determinate, however, in Bone; for not only do we find that in the first development of this substance, a considerable part of the tissue originally generated by the consolidation of its osseous or cartilaginous matrix speedily disappears, and that during the whole period of growth of the shaft of a round bone,

there is a continual removal of its inner and older portions, whereby the medullary cavity is progressively enlarged; but there is strong evidence that, even after the bone has attained its full dimensions, a replacement of old Haversian systems by new is continually in progress (§ 348).

III. In the case of the Muscular and Nervous tissues, however, we trace the operation of causes that differ from any of those already specified. These tissues are doubtless subject, like all others that are distinguished by their vital activity, to the law of limited duration; for we find that, when not called into use, they undergo a gradual disintegration or wasting, which is not adequately repaired by the nutritive processes. But their existence as living structures appears to be terminable at any time by the exercise of their functional powers; for the development of muscular contractility or of nervous force seems to involve, as its necessary condition, a metamorphosis (so to speak) of the vital power which was previously exercising itself in the nutritive operations; and the materials of these tissues, now reduced to the condition of dead matter, undergo those regressive changes which speedily convert them into excrementitious products. But the very manifestation of their peculiar vital endowments, determines an afflux of blood towards the parts thus called into special activity; and from this it comes to pass, that the nutrition of these textures is promoted, instead of being impaired, by the losses to which they are thus subjected; so that their constant exercise occasions an augmentation, rather than a diminution, of their substance,—a due supply of the requisite materials being always presupposed.

345. Thus it comes to pass, that during the whole period of active life, a demand for Nutrition is created by every exertion of the vital powers, but more especially by the evolution of the Nervous and Muscular forces. The production and application of these, indeed, may be considered as the great end and aim of the Human organism, so far at least as the individual is concerned; the whole apparatus of Organic life being subservient to the building-up and maintenance of the Nervo-muscular apparatus, and of those parts of the fabric (*e. g.* the bones, cartilages, fibrous textures, &c.) which it uses as its mechanical instruments. Thus the activity of all the Organic operations, when once the full measure of growth has been attained, is mainly determined by that of the Animal functions; and as the 'rate of life' of all the parts which minister to the former, will be proportioned to the energy with which they are called-upon to perform their functions, their duration will diminish in the same proportion, and hence occasion will arise for their continual renewal.* But since, in the attainment of the adult con-

* Such an excellent illustration is afforded by the phenomena of Vegetation, of the doctrines here propounded, that it scarcely appears desirable to pass it by in this place, although it has been elsewhere more fully referred to ("PRINC. OF COMP. PHYS.," §§ 357, 358).—The leaves of Plants serve, like the absorbing and assimilating cells of Animals, for the introduction and elaboration of the nutritive materials which are to be applied to the extension of the fabric; the more permanent and inactive parts of which are thus generated at the expense of materials prepared by the vital operations of the more transitory and energetic (§ 20). Now there is an obvious limit to the duration of the leaf-cells; but this limit is not precisely one of *time*, being rather dependent upon the *completion of their series of vital actions*. Thus, although we are accustomed to look upon the 'fall of the leaves' (which is nothing else than an exuviation consequent upon death) as a pheno-

dition, the productive capacity has undergone a gradual diminution, whilst the exercise of the animal powers has become vastly increased, the formative processes are only capable of *maintaining* the organism in its state of completeness and vigour, by making-good the losses consequent upon the continual disintegration to which it is subjected by its nervo-muscular activity. And with the advance of years, the further diminution of the productive capacity involves,—on the one hand, a progressive decrease in the substance of the tissues and organs most important to life (their bulk, however, frequently remaining unchanged, or even increasing, in consequence of the accumulation of fat),—and on the other, a gradual weakening of its powers of action. (See CHAP. XVIII.)

346. The performance of the function of Nutrition, the demand for which arises out of the causes that have been now discussed, is dependent, not merely upon a due supply of pure and well-elaborated blood, but also upon the normal condition of the part to be nourished, and especially upon its possession of a right measure of 'formative capacity;' in virtue of which, the newly-produced tissues are generated in the likeness, as well as in the place, of those which have become effete. The exactness of this replacement is most remarkably shown in the retention of the characteristic form and structure of each separate organ or part of the body, and thus of the entire organism, through a long series of years; no changes being apparent (so long as the state of health is preserved), but such as are conformable to the general type of that alteration which the organism undergoes with the advance of life. And not only is this to be noticed in the conservation of all those distinguishing points of structure which mark the species, and are essential to its well-being; but it is still more remarkably displayed in the continuous renewal of those minor peculiarities, which constitute the characteristic features of the individual, and which serve to distinguish him from his fellows. And how much this depends upon the formative capacity originally derived from the germ, is evident from this, that a similar moulding (so to speak) of the nutritive material takes place, in its original development, at first into the form characteristic of the species, and afterwards into that which marks the individual; and that the peculiarities of the individual are frequently such as have been distinctive of one or other of the parents, or present a combination of both. But it is curious that the formative power should often be exercised, not only in maintaining the original type, but also in keeping-up some acquired peculiarity; as, for example, in the perpetuation of a cicatrix left after the healing of a wound. For, as Mr. Paget has remarked, the tissue of a cicatrix grows and assimilates nutrient material, exactly as do its healthy neighbouring tissues; so that a scar which a child might have said to be as long as his own fore-finger, will still be as long as his fore-finger when he becomes a man. And when the mode of nutrition in any part has been altered by disease, there is frequently an obstinate tendency to the perpetuation

menon of regular seasonal recurrence, and to regard their replacement by a new growth as occurring at a not less constant interval, yet experience shows that these intervals are entirely regulated by temperature; for if one of the ordinary deciduous trees of temperate climates be transferred to a tropical climate, it will live much faster, its leaves being shed far more frequently, and being replaced much more speedily; so that two, or even three, successive exuviations and reproductions of its foliage may take place within a year.

of the same alteration; or, if the healthy action be for a time restored, there is a peculiar tendency to the renewal of the morbid process in the part; and this is stronger the more frequently it recurs, until at last it becomes inveterately established. There is, however, in the Tissues generally, as in the Blood (§ 223), a general tendency to a return to the normal type, after it has undergone a temporary perversion; and hence it is, that we find the typical structure of parts gradually restored, when the morbid tendency has been overcome, and that even cicatrices and indurations, notwithstanding their usual obstinate persistence, occasionally disappear. The normal type is, perhaps, less likely to be thus recovered, when the departure from it is very slight, and consists rather in the wrong plan (so to speak) on which the new matter is laid-down, than in a perversion of the nutritive process itself.

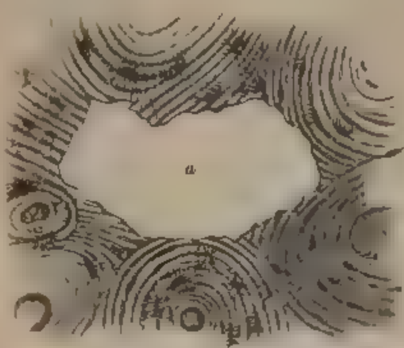
347. Of the mode in which the substitution of new tissue for that which has become effete, is effected in the process of Nutrition, our knowledge is at present limited; but there can be little doubt that it nearly always takes place in a manner closely conformable to the true development of each tissue. In some instances, there is an obvious *replacement* of the old and dead by the young and active elements; this is the case, for example, in the constantly-repeated production of the Epidermic and Epithelial layers, for whether they are developed from germs imbedded in the subjacent basement-membrane, or from nuclei formed *de novo* in the blastema on its free surface, or by the duplicative subdivision of pre-existing cells, there is a continual succession of new cells, which take the place of those that are cast-off as defunct and useless. So in the growth of Hair, the increase of which takes-place only at its base, we can trace at any period the same development of newly formed spheroidal cells into horny fusiform fibres, as that which occurred when first the hair began to sprout from the aggregation of epidermic cells at the bottom of its follicle. So, again, in the vesicular tissue which constitutes the essential part of the Nervous centres, there are appearances which indicate that its peculiar cells are in a state of continual development, newly-formed ganglionic vesicles taking the place of those which have undergone disintegration. But there are other textures, whose nutrition is more completely *interstitial;* their elements being more closely coherent, and their newly formed portions being developed throughout the substance of the old, instead of (as in the case of the epidermis and its appendages) *superficially* or in mere continuity with it. Such is the case, for example, with Muscle, the mode of whose nutrition has not yet been elucidated. We can only infer from analogy, that here too each fibre or fibril will pass, in the course of its development, through the same stages which those of the embryo did when its muscles were first formed. And this analogy seems to derive support, from the presence, in all well-nourished muscles, of bodies which bear the appearance of nuclei, for these, as Mr. Paget remarks, "are not the loitering impotent remains of embryonic tissue, but germs or organs of power for new formation." And it is further confirmatory of this view that losses of substance of muscle which involve the destruction of these centres of nutrition, are not replaced, like losses of cuticle, by new tissue of the same kind; the power to form it not being inherent in the blood or in the neighbouring parts. Nevertheless it must be admitted

that no intermediate stages of development can be traced in the fibres, even of those muscles of the adult which are in most constant use, and of which the nutrition is the most active, that are at all comparable to those which are met-with in the muscular tissues of the embryo.—With regard, again, to the interstitial nutrition of Bones and Teeth, we know nothing whatever. That some movement of nutritive fluid is continually taking place through them, is made apparent by the effects of madder in gradually tinging even the bones and teeth of the adult, though for such a change a much longer period is required in the adult than in the young animal; how far this movement, however, is subservient to any continual change of substance, still remains doubtful. If the supply of blood be withdrawn from a tooth or from a bone, or even from a part of the latter, the structures thus cut-off from connection with the act of nutrition, soon die, become detached from the living parts around, and are thrown-out of the body. Of this we have a very good example in the annual exuviation of the antlers of the Deer, which is brought-about by the choking-up of the Haversian canals that give passage to blood-vessels, with concentric osseous deposit. Something of this kind seems to be continually taking-place in ordinary Bone, upon a more limited scale, individual Haversian systems being removed by absorption, and being replaced by new formations of the same kind, probably during its whole life, without any change in external configuration (§ 348).

348. Of the modes in which the effete particles of tissues whose term of life has expired, or whose vital energy has been exhausted, are removed and disposed-of, our present knowledge is no less imperfect. In the case of those tissues which are *superficially* nourished, a continual loss of substance is obviously taking place, by the exuviation of dead particles *en masse*; this is the case with the whole series of Epithelial and Epidermic cells, which are thrown-off with little previous change, like the leaves of trees, their decay not taking place, for the most part, until after they have become detached from the organism. But the fact is altogether different with regard to those whose nutrition is *interstitial*, especially the Nervous and Muscular tissues; for the decomposition of these would seem to occur in their very substance, its products being taken-up by the blood, and subsequently eliminated from it by organs appropriated to that purpose, as is indicated by Chemical evidence. For on the disintegration of the albuminous constituent of Muscle, it appears to resolve itself into two classes of compounds; one of them rich in carbon, the other in nitrogen; the former is represented in the 'juice of flesh' (the peculiar 'extractive' of which is much increased in amount by exercise of the muscle) by inosite or muscle-sugar, by lactic acid, and under certain conditions, by fat; the latter by creatine and creatinine. The former class of products is taken-up into the blood, to be eliminated from it, partly through the intermediation of the liver, by the respiratory process; the latter is in like manner conveyed by the circulating current, to the kidneys, the creatine being for the most part converted into urea. As regards the Nervous substance, however, no equally definite proof of this kind can at present be afforded, since its normal constitution is not yet sufficiently understood, to enable the products of its disintegration to be certainly distinguished.—A remarkable indication has been recently afforded, by the microscopic examination of Bone, that

the older portions of its substance are removed from time to time, and that space is thus provided for the deposit of newly-formed tissue in its stead. For transverse sections of long bones usually exhibit, in some

Fig. 52.



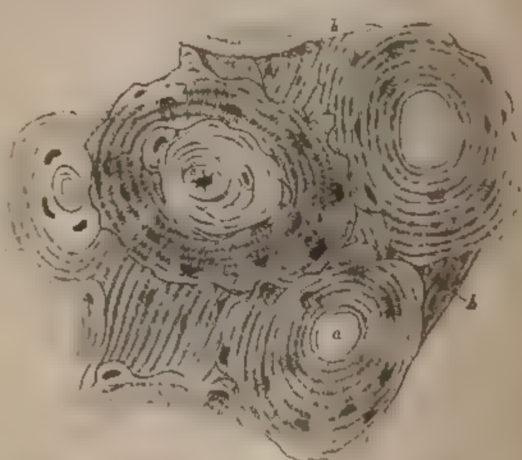
Transverse section of compact *Bone*, showing an *Haversian space*, *a*, with its characteristic emarginated outline

Fig. 53.

The same, from a less compact part of the bone

part of their area, irregularly-shaped spaces, having an emarginated, festooned, and often jagged outline (Figs. 52, 53), similar to that found on

Fig. 54



Transverse section of compact *Bone*, showing the ordinary appearances,—*a*, Haversian system; *b*, *b*, interstitial laminæ, *c*, new Haversian system within an older one

the surface of bone which has been removed by exfoliation, or to that of the fang of a tooth which has been partly absorbed. There is every indication, from a comparison of the various conditions presented by

these 'Haversian spaces,' both as to form, size, and situation, that they are left by the partial or complete removal of 'Haversian systems,' which previously occupied the same situations. They are exceedingly numerous and large in newly-formed bone situated near ossifying cartilage, so as frequently to afford room for the development of two or more 'Haversian systems' in their interior; while in older bone they are far less numerous, and generally less in size, so that by the excavation of one of these spaces within an old 'Haversian system,' a new one may be formed of much smaller dimensions (Fig. 54, *c*). The persistence of portions of those older 'Haversian systems' which have undergone partial absorption, appears to account for the presence of the 'interstitial laminæ' (*b*, *b*), which fill-up the spaces between the existing 'Haversian systems,' and of which, as they have not any obvious centres of nutritive supply, no other satisfactory explanation can be given. Such appearances, indicative of alternate acts of absorption and reproduction, are seen in the bones of old as well as of young or middle-aged subjects; but their frequency diminishes with the increasing age of the individual.*—So far as can be gathered from the foregoing facts, and from others of the same order, the process of interstitial decline and death usually takes place too rapidly for its stages to be perceptible, and is *immediately* followed, in the normal condition of the system, by the removal of the effete particles; so that it is only when this removal is from any cause obstructed, as happens in the cases to be presently cited, that we see any indication of the *stages* through which the disintegrating tissues pass.†

349. There is one remarkable form of degeneration, however, which is common to nearly all the tissues, and which seems to occur as a normal alteration in many of them at an advanced period of life; this consists in the conversion of their albuminous or gelatinous materials into fat, thus constituting what is known as *fatty degeneration*. That this change is not due to the removal of the normal components of the tissues, and the substitution of newly-deposited fatty matter in their place, but is (in most cases at least) the result of a real conversion of the one class of substances into the other, may now be considered as well ascertained.‡ And there are certain facts which indicate that this kind of degeneration is a part of the regular series of processes, by which tissues that have served their purpose in the economy are prepared for being removed by absorption; one of the most remarkable being the observations of Virchow§ and Kilian‖ with regard to the fatty degeneration of the muscular tissue of the uterus after parturition. So, as Mr. Paget has pointed-out, the fibrinous and corpuscular products of

* See the Memoir by Messrs. Tomes and De Morgan 'On the Structure and Development of Bone,' in "Philos. Transact.," 1853, p. 111.

† Fully recognizing the importance of Dr. Lyon's ingenious enquiries on 'Histolysis' (see "Proceed. of Royal Irish Acad.," vol. v., part iii., and "Brit. and For. Med.-Chir. Rev.," vol. xii., pp. 454, 532), the Author cannot regard the changes which take place in tissues decomposing out of the body, as throwing much light upon the processes of degeneration that take place during the latter period of their life.

‡ For a very complete view of the present state of our knowledge of the whole subject of Fatty Degeneration, see Dr. Handfield Jones's Articles in the "Brit. and For. Med.-Chir. Rev.," vol. xi., p. 327, and vol. xii., p. 30.

§ "Verhandlungen der Gesellschaft für Geburtshülfe," Berlin, vol. iii. p. xvii.

‖ "Henlé und Pfeuffer's Zeitschrift," vol. ix. p. 1.

inflammation are often brought into a state fit for absorption, by passing through this intermediate stage; the fibrinous substance being observed to be dotted by granules, which are known to be oil-particles by their peculiar shining black edged appearance, and at the same time losing its toughness and elasticity, and being no longer rendered transparent by acetic acid; whilst the lymph-cells present a similar increase of shining black-edged particles like minute oil-drops, which accumulate until they nearly fill the cell-cavity, their nuclei at the same time gradually fading and disappearing.* Thus, then, if the fat, which is one of the products of this regressive metamorphosis, be absorbed as fast as it is formed, and the effete tissue be replaced by a new production (as seems to be the case with Muscles in a state of healthy activity), there is no appearance of degeneration, and the nutrition is kept-up to its normal standard. So if, from the advance of age, or from the insufficient exercise of the muscles, their nutrition take place less rapidly than their waste, whilst the products of their degeneration are still removed, simple atrophy is the result. If, on the other hand, the general conditions being similar, the fat produced in degeneration be not absorbed, but remain in the tissue, an obvious 'fatty degeneration' is the result. This seems most likely to happen either (1) when the fat is thus produced in such excessive amount, that the ordinary rate of its absorption (corresponding with that of its elimination by the combustive process) does not provide for its removal; which will occur when a large amount of tissue is undergoing degeneration at once, as in the case of the uterus after parturition: or (2) when the blood, being already highly charged with respiratory material, is indisposed to receive an additional amount of fat; and it is probably in part from this cause, that the habitual presence of Alcohol in the blood strongly predisposes to fatty degeneration, as is proved by the very large proportion of intemperate individuals among the subjects of the more aggravated forms of this disorder. For the extraordinary aptitude for the combustive process which is characteristic of Alcohol, gives it such a preference in this operation over the ordinary combustive material, that the conversion of the latter by oxidation into carbonic acid and water is kept back, so long as Alcohol is present; and thus the blood of drunkards becomes so highly charged with fat, that it might be itself considered to be in a state of fatty degeneration.† This distinct indication of the operation of Alcohol habitually received into the blood in large quantities, affords an obvious indication that the habitual consumption of even a much smaller amount will tend to produce fatty degeneration at more remote periods and in a less aggravated degree; and the participation which this state has been shown to have in the production of a large proportion of the diseases of Old Age, especially by the changes it induces in the texture of the heart and of the walls of the bloodvessels (which are particularly liable to it),—fully bears out this idea.

* See Mr. Paget's "Lectures on Surgical Pathology," vol. i. p. 374.

† The quantity of fat in the blood of drunkards has been found in some cases to be as much as 117 parts in 1000; Lecanu's highest estimate of the quantity in health being 8·65 parts. Scharlau has found as much as 30 per cent. more carbon in the blood of a drunkard, than in that of a healthy man. See Dr. Huss's treatise on "Alcoholismus Chronicus," Rokitansky's "Handbuch der allgemeinen pathologischen Anatomie," band i., and "Brit. and For. Med. Chir. Rev.," vol. xi., pp. 33, 34.

350. It may be stated as a general rule, that no absorption of the materials of tissues can take-place, without a previous degeneration such as this, or a more complete decomposition. There is no evidence that any *healthy* tissue is ever thus absorbed, or that any preternatural activity of the absorbent vessels can ever (as formerly supposed) be the *occasion* of a loss of substance; in fact, so long as the vital force is in active operation in a part, and its processes of growth and development are being normally carried-on, such absorption may be considered to be impossible. On the other hand, if a part die *en masse*, it is not removed by absorption, but becomes isolated by the separation and recedence of the living parts, and is then cast-out altogether, even from the interior of the body, as we see in the case of a necrosed bone; its condition being then essentially the same as that of the outer layers of the tegumentary organs, which are cut-off, by their distance from a vascular surface, from all further nutrient change. The difference between these two modes of removal is well seen (as Mr. Paget has remarked) in the case of the Teeth, for the fangs of the deciduous teeth undergo degeneration, when the current of nutrition is diverted towards those which are to succeed them, their materials being slowly decomposed so as to become soluble, and being gradually removed by absorption, so that nothing is left at last but the crowns of the teeth; on the other hand, the permanent teeth, which are not to be succeeded by others, when no longer receiving their due nutrition, die, and are cast-out entire.

351. Among the conditions of healthy Nutrition, a due supply of Nervous power is commonly enumerated; and it cannot be questioned that the want of such a supply is frequently the source of a perversion of the normal operations. This, however, by no means proves that the formative power is derived from the nervous system; and such an idea is at once negatived by a number of incontestible facts (§ 33). Yet it may be freely admitted that the right direction and application of this power in Nutrition, may sometimes depend upon guidance and direction afforded by the Nervous centres, in the same manner as the Secreting process is capable of being thus affected; in fact we can scarcely explain in any other mode that influence of mental states upon the nutrient operations, which frequently leads to very important modifications of them. The whole of this subject, however, will be more appropriately considered hereafter (CHAP. XV).*

2. *Varying Activity of the Nutritive Processes.—Reparative Operations.*

352. Without any change in the *character* of the Nutritive processes, there may be considerable variations in their *degree of activity*; and this, as regards either the entire organism, or individual parts, though most commonly the latter. These variations may be so considerable as to constitute Disease; though there are some which take place, as part of the regular series of Physiological phenomena. Thus, as we have seen, it is to the excess of formative activity, that the increase of the organism in the earlier period of life is due, its 'waste' being at the same time

* In the treatment of this subject, the Author has made use of many valuable illustrations contained in the first three of Mr. Paget's "Lectures on Surgical Pathology," the general doctrines, however, being such as he had himself expressed on many previous occasions.

extremely rapid; whilst it is to a corresponding reduction in the regenerative power, and not to positive excess of 'waste' or decay (this, indeed, taking place very slowly), that the gradual decline of the organism in advancing years is to be attributed. So also we find that local as well as general variations may take place, as a part of the regular series of vital phenomena; and this during the period of adult life, as well as in the earlier and later epochs. Thus all those differences in the proportional development of the several parts of the organism, which mark the distinction between the adult and the child, even where (as in the case of a dwarf), there is no difference in stature, result from a decline in the formative capacity of those which are peculiarly adapted to the wants of the earlier stage (the Thymus gland, for example), and from an increased activity of nutrition in those which are destined to the use of the adult, the Generative organs more particularly. And the intermittent activity of the sexual apparatus of the female affords a remarkable example of the same principle, this being marked, not merely in the enormous development of the uterus and mammary glands as a consequence of conception, but in the periodical change which takes place in the ovaries, whereby the ova are matured and thrown-off at certain regular intervals. The decline in the formative power of these same organs, moreover, when as yet the organism in general shows but little indication of deterioration, is another characteristic example of the variation in Nutritive activity resulting from the inherent endowments of the part, and essentially irrespective of the condition of the blood, of the circulation, and of the organism as a whole; although, as formerly shown (§ 219), the production and maintenance of other and apparently unconnected organs are *complementally* dependent upon the formative activity of the Generative apparatus.

353. The abnormal excess of Nutritive change which properly constitutes *Hypertrophy*, appears to depend upon a departure from one or other of the conditions, under which, as already specified, the change normally takes place; namely, the right composition of the blood, a due supply of such blood, and a proper formative capacity in the part itself. Of the excess of nutrition resulting from the presence of an excess of the peculiar materials of certain tissues in the circulating fluid, examples have already been given (§ 340); it is important to remark, however, that although hypertrophy may be thus induced in any of the tissues which constitute the instruments of *organic* life, yet there is no evidence that either the Nervous or the Muscular apparatus can be forced (so to speak) to an augmentation in bulk, by the mere abundance of their nutritive materials.

With regard, in the next place, to the supply of blood, there can be no doubt that in general an increased flow of blood towards a part is consequent-upon, rather than a cause-of, an excess in its nutritive activity; but still there are cases in which its causative agency may be traced. Various examples of this have been supplied by the experiments and observations of John Hunter, the records of which are left in his Museum. Thus if the spur of a cock be transplanted from the leg to the comb, which is a part far more vascular than that with which it was originally connected, it undergoes an extraordinary augmentation in size; having in one instance grown in a spiral form, until it was six inches long; and in another, curved forwards and downwards like a horn, so that its end needed to be often cut, to enable the bird to bring its beak to the ground

in feeding. So, again, it was remarked by Hunter, and has been frequently observed since, that an increased growth of hair often takes place on surfaces to which there is an increased determination of blood as a consequence of inflammation in some neighbouring part, though not from the surface of the inflamed part itself. So it sometimes happens, that when an ulcer of the integuments of the leg has long existed in a young person, the subjacent bone may share in the increased afflux of blood, and may enlarge and elongate. And it seems not improbable that we are to attribute the increased thickness of the cuticle, on parts which are exposed to continual pressure or friction, to the augmented afflux of blood which is determined to the irritated surface.*

354. The greater number of cases of Hypertrophy, however, must undoubtedly be referred to the preternatural formative capacity of the part itself; and this may either be congenital or acquired. Of this congenital excess, we have a remarkable example in the abnormal growth of an entire limb, or of fingers or toes,† which cannot with any probability be referred to an original excess in the supply of blood, the enlargement of the arteries leading towards such parts being almost certainly consequent upon their unusually rapid growth, just as in the case of the uterine and mammary arteries of the pregnant female. The most remarkable instances of the acquirement of increased formative activity, are presented to us in that augmented growth of the nervous and muscular tissues, which is consequent upon the exercise of their functional powers. This may be considered as to a certain extent a normal adjustment of the supply to the demand; but there are some instances in which it takes place to such an extent, as to become a positive disease. Thus it not unfrequently happens, that if young persons who naturally show precocity of intellect, are encouraged rather than checked in the use of the brain, the increased nutrition of the organ (which grows faster than its bony case) occasions pressure upon its vessels, it becomes indurated and inactive, and fatuity and coma may supervene. Now although in such cases there must probably have been some congenital tendency to preternatural activity of the brain, which manifests itself in the precocity of intellect, yet there is no doubt that this may be augmented by the 'forcing system' of education; whilst, on the other hand, it may be controlled by a system of management adapted to the peculiar circumstances of the case. Excess of muscular development is peculiarly prone to show itself in the involuntary muscles; but this production is in almost every instance the result of the demand for increased muscular exertion, which is consequent upon some obstruction to the usual function of the part. Thus an extraordinary hypertrophy of the muscular coat of the urinary bladder is often seen as a consequence of obstruction to the exit of the urine, through the presence of a stone in the bladder or of a stricture in the urethra; so, again, hypertrophy of the muscular coat of the gall-bladder may take-place as a consequence of obstruction of its duct by a

* It is commonly said that local Hypertrophy may be induced by long-continued Congestion, but this is not true hypertrophy, for the bulk of the organ is not augmented by the increased production of its normal tissue, but by the addition of tissue of an inferior type of organisation, as in Inflammation (§ 369).

† A case of hypertrophy of an entire limb was described by Dr. John Reid in the "Edinb. Monthly Journ.," 1843, p. 198, and several cases of hypertrophy of the fingers were described by Mr. Curling in the "Med.-Chir. Trans.," vol. xxviii.

gall-stone; hypertrophy of the muscular coat of any part of the alimentary canal may be induced by the existence of stricture lower down, and even hypertrophy of the heart is generally, if not always, attributable to obstruction to the exit of the blood which it propels, resulting either from stagnation of the pulmonary circulation by the deficient aeration consequent upon disease of the lungs (in which case the hypertrophy is limited to the right side of the heart), or from thickening or induration of the semilunar valves, or from narrowing of the orifices of the aorta and pulmonary artery. It is curious, moreover, to observe that hypertrophy of muscles frequently becomes a source of increased nutrition of the bones to which they are attached: this being manifested, not merely in the augmented bulk of the bones of limbs that are specially exercised, but also in the increased prominence of the ridges and processes to which the muscles are attached. This adaptiveness on the part of the formative activity of the osseous tissue, is curiously manifested also in the relation of the skull to the brain; for if the bulk of the brain be not too rapidly augmented, the skull will enlarge accordingly, and this (in some instances) not merely by the extension of its normal bones, but by the intercalation of new osseous elements, the 'ossa wormiana;' whilst, on the other hand, if there be a diminution in the bulk of the brain, the cranium may adapt itself to this also, by a thickening on its internal surface (or concentric hypertrophy), —this change, rather than a diminution in the entire substance of the skull, being more liable to take place in cases in which the cranial sutures have already closed, and the nutrition of the bone has become inactive.

355. The production of *Tumours* must be considered as a manifestation of an excess of formative activity in individual parts, and as constituting, therefore, a species of Hypertrophy. For a tumour may be composed of the tissues which are normal to the part; as we see especially in the case of those tumours of the uterus, which are made-up of an excess of its ordinary muscular and fibrous elements. But, as Mr. Paget has justly remarked, "an essential difference lies in this,—the uterus (often itself hypertrophied) in its growth around the tumour maintains a normal type, though excited to its growth, if we may so speak, by an abnormal stimulus; it exactly imitates, in vascularity and muscular development, the pregnant uterus, and may even acquire the like power; and at length, by contractions like those of parturition, may expel the tumour spontaneously separated. But the tumour imitates in its growth no natural shape or construction; the longer it continues, the greater is its deformity. Neither may we overlook the contrast in respect of purpose, or adaptation to the general welfare of the body, which is as manifest in the increase of the uterus as it is improbable in that of the tumour."* A gradation is established, however, between true Hypertrophies and Tumours, by those productions of glandular tissue, which are made-up of the proper substance of the gland with which they are connected, as the mammary, the prostate, or the thyroid, and which (though frequently encysted) are sometimes met-with as outlying portions of the gland itself.—There is another class of objects, to which Tumours come into close relation, and which must be referred, like them, to a local excess of formative activity.

* See his "Lectures on Surgical Pathology," vol. ii. p. 2; also Dr. Handfield Jones in "Brit. and For. Med.-Chir. Rev.," vol. xiii. p. 330; and Dr. Bristowe in "Trans. of Pathol. Soc.," vol. iv., p. 218.

these are the "supernumerary parts" which are not unfrequently developed during fœtal life, as for example, additional fingers and toes. It seems absurd to refer these, formed as they are by simple outgrowth from the limbs to which they are attached, to the "fusion of germs" which has been hypothetically invoked to explain more important excesses, as those of additional limbs, double bodies, or double heads; and yet from the lower to the higher form of excess, the transition is so gradual, that what is true of the former can scarcely but be true of the latter. Hence even complete "double monsters" must be regarded, not as having proceeded from two separate germs which have become partially united in the course of their development, but from a single germ, which, being possessed of an unusual formative capacity, has evolved itself into a structure containing more than the usual number of parts, and comparable to that which may be artificially produced by partial fission of the bodies of many of the lower animals.*

356. We can scarcely fail to recognize, throughout this whole series of abnormal productions, the operation of a similar power. In the formation of a supernumerary part, this has been sufficient, not merely to produce the tissues, and to develope them according to a regular morphological type, but to impart to the fabric thus generated a separate and even an independent existence; thus evolving an additional finger or thumb on each hand, a double pair of arms or legs, a double head or trunk, or even a complete double body. In the hypertrophy of a regular or normal part, the new tissues are still developed according to a regular morphological type; but they have not the power of individualizing themselves (so to speak), and are so incorporated with the normal elements as to augment the size of the existing organ. In the formation of a tumour, on the other hand, whilst its component tissues are themselves perfectly formed, and have a marked power of independent growth, the mass composed of them is altogether amorphous, its configuration being usually determined rather by the physical conditions under which it is produced, than by any peculiar tendencies of its own; so that we recognize the action of the formative power, undirected by that morphological *nisus*, which normally models (so to speak) the growing tissues into the likeness of the organ to which they belong. But further, in many of the large class of tumours distinguished as 'malignant' (§ 378), the development of tissue has not gone to the extent of producing any of those species of which the body is normally constituted; and in this respect, as well as in their tendency to rapid degeneration, the vital endowments of their elements must be reckoned as below those of the normal tissues.—It is not always easy to draw the line between certain tumours and supernumerary parts, especially when the production of the former is symmetrical; but the first appearance of the latter never takes place save during embryonic life, and their structure is more complex, and is more conformed to the plan and construction of the body at large, than is that of tumours, whose production may take-place at any period of life. And between those tumours which are known as 'piliferous' and 'dentigerous cysts,' and those encysted embryoes (usually incomplete in

* See "Princ. of Comp. Phys.," § 475; Prof. Vrolik in "Cyclop. of Anat. and Phys.," art. 'Teratology,' vol. iv. p. 976, and Prof. Allen Thomson on 'Double Monstrosity,' in "Edinb. Monthly Journal," June and July, 1844.

their formation) which are sometimes found in the bodies even of males, it is impossible to establish any line of demarcation sufficiently precise, to prevent our recognizing them as all having the same origin, and being expressions of the same power,—the simple cyst being a kind of rude attempt at the production of a distinct individual,—and the encysted embryo being but the result of an unusually high development of a proliferous cyst.

357. The state of *Atrophy* is in all respects the very opposite of that of Hypertrophy; consisting in such a reduction in the rate of formative activity of parts, as compared with that of their 'waste,' that their nutrition is no longer maintained at its previous standard; so that they are gradually reduced in bulk, or degenerate into some inferior histological type, or (which is more common) undergo both diminution and deterioration at the same time. It is important to bear in mind, that Atrophy may take place, either locally or generally, from an unusually-rapid disintegration of the tissues, uncompensated by a corresponding increase in the rate of their nutrition: of such local atrophy, we have a characteristic example in the rapid reduction of the bulk of the uterus after parturition, and of the mammary glands after the sudden cessation of lactation; of the general, we see an illustration in that rapid wasting of the system, which takes place in the irritable state that results from excessive and prolonged exertion of body or anxiety of mind, especially when accompanied with want of sleep, the increased disintegration being marked by the presence of an unusual amount of urea and of the alkaline phosphates in the urine. But in the ordinary forms of Atrophy, there is not merely a *relative* but an *absolute* reduction in the rate of the formative process, or a lowering of its standard of perfection; and here also we have to look for its causes, on the one hand, in the condition and supply of the blood, and, on the other, in the formative capacity of the tissues themselves.—The Atrophy dependent upon an insufficient supply of nutritive materials, may be either general or partial. General atrophy, or emaciation, is a necessary result of deficiency of food; but it may also proceed from an imperfect performance of the assimilating processes, whereby the nutritive materials do not receive their requisite elaboration, as in cases of disease of the mesenteric glands; or from an unusual energy of the metamorphic processes, whereby the azotized constituents of the food are decomposed into excrementitious products, without undergoing assimilation at all, as seems to be the case in diabetes. Of the atrophy of a particular tissue, consequent upon the deficiency of its proper materials in the blood, we have an example in the reduction of the adipose, when there is no surplus of fatty matter to serve for its nutrition, but on the other hand a withdrawal of the contents of the fat-cells into the circulating current, whilst the nutrition of the muscular and other azotized tissues may proceed with its usual vigour.—Instances of complete local atrophy or gangrene, resulting from deficiency in the supply of blood to a part, are by no means unfrequent; but it is less common to meet with a prolonged diminution in the rate of nutrition from such a cause, since a partial obstruction to the circulation is usually removed after a short time by the enlargement of the collateral vessels. Yet there are peculiar circumstances under which this does not take place; thus Mr Curling has shown that atrophy may occur in that portion of a fractured bone

which is cut-off from the direct supply of blood through the great medullary artery, the circulation being restored by anastomosis to such an extent as to prevent the death of the bone, but not so completely as to support vigorous nutrition.*

358. The most frequent cause of Atrophy lies, however, in the deficiency of formative power in the tissues themselves, arising from the decline of that capacity which they inherit from the germ. This decline, as already shown, takes place in the body at large, as a part of the regular order of things, with the advance of years, and also normally occurs in particular organs at earlier periods of life; but it sometimes takes place prematurely, either in the body at large, or in particular organs, so that they undergo a wasting or degeneration without any ostensible cause. Thus it is not at all uncommon for Articular Cartilages to be almost entirely destroyed through defect of nutrition, without any pain or other symptoms to call attention to the change in progress,† and many similar cases might be cited. There is reason to believe that 'fatty degeneration,' the form under which degeneration most commonly presents itself (§ 349), is in reality far more frequent than simple wasting; but it attracts less notice, because the bulk of the tissues is little or not at all diminished; and it is only when their function becomes impaired, that attention is seriously drawn to the change. This form of Atrophy can seldom be attributed to antecedent diminution in functional activity; for it is most common in organs upon which there is the most constant demand for the energetic performance of their respective duties, as, for instance, in the heart, the kidneys, and the liver. But the formative activity of Muscles and Nerves is so closely dependent, as already several times pointed-out, upon the active exercise of their functional powers, that atrophy is certain to supervene if this be interrupted; and this atrophy may or may not present itself under the form of fatty degeneration; a shrinkage of the parts, concurrently with the production of an increased amount of fat in them, being perhaps the mode in which it most frequently takes place. Atrophy of one part, moreover, may be dependent upon atrophy or imperfect functional activity of another, if the two be so related in their normal functions, that a decline of one involves a corresponding decline in the other. Thus if a motor nerve be paralyzed, the muscles which it habitually calls into action will be atrophied; and this will equally happen, whether the want of motor power depend upon a deficient production of it in the nervous centres, or upon an interruption to its conduction through the trunks.‡ On the other hand, if the

* "Medico-Chirurgical Transactions," vol. xx.

† See Redfern, "On Abnormal Nutrition in Articular Cartilages," p. 65.

‡ The Author has for some time had under his observation a case in which three males of a family have progressively become affected, between the ages of 3 and 5 years, with fatty degeneration of the muscles, which has proceeded in the most advanced case to the almost complete obliteration of their normal structure. This change had been considered by many eminent Practitioners to be idiopathic, that is, to have its primary origin in the muscular tissue, and the measures which had been employed to arrest it had been of no avail whatever. It was a strong argument, however, against such a view of the case, that, in the *heart* of the eldest son, who died of fever at the age of 16, no fatty degeneration could be discovered, and on making inquiry into the history of the parents and of their families, ample evidence was discovered for the belief, that the disease was dependent upon the want of functional power in the nervous centres. Acting on this view, it was recommended that the muscular system should be kept as much as possible in a state of active

muscles of a part undergo degeneration from want of use (as in disease of the hip-joint), the nerves which supply them also suffer. The same is the case in regard to the nerves and organs of sense: for atrophy of the eye will occasion atrophy of the optic nerve, and destruction of the optic ganglia will induce atrophy of the eyes and optic nerves. Even the bones of a limb will suffer, in cases of atrophy of the muscles consequent upon disuse; for in an experiment made by Dr. J. Reid, to determine the effect of artificial exercise in maintaining the nutrition of muscles whose nerves had been divided, the bones of the quiescent limb only weighed 81 grains, whilst those of the exercised limb weighed [illegible] grains.*—It is an important fact, which was first pointed-out by Mr. Paget,† that when fatty degeneration is commencing in any tissue, which is characterized by the persistence of its nuclei, it is in the nuclei that the first alterations are seen; for they become pale and indistinct, and may even disappear altogether, almost before any other change is discernible in the contents of the cells or tubes to which they appertain; but in atrophy from mere decrease, this disappearance of the nuclei does not occur.

359. *Reparative Process.*—The nutritive operations take place with extraordinary energy and rapidity, in the process of *Reparation*, by which losses of substance, occasioned by injury or disease, are made good. In its most perfect form, this process is exactly analogous to that of the *first development* of the corresponding parts; and its results are as complete in the one case as in the other. In fact, among the lowest tribes of Animals, we find these two conditions blended, as it were, together; for the process of reparation may be carried in them to such an extent, as to reproduce the whole organism from a very small portion of it. In the Hydra, or Fresh-water Polype, there would seem to be scarcely any limit to this power; for, even if the body of the animal be minced into small fragments, every one of these can produce a new and perfect being. In this manner, no less than forty have been artificially generated from a single individual.—In ascending the Animal scale, we find this reparative power less conspicuous, because limited in its exercise to particular tissues and to comparatively insignificant parts of the body;‡ and in Man, as in other warm-blooded Vertebrata, the regenerative power is for the most part restricted in its exercise, as Mr. Paget has pointed-out,§ to three classes of parts;—namely, (1). "Those which are formed entirely by nutritive repetition, like the blood and epithelia (their germs being continually generated *de novo* in the ordinary condition of the body). (2.) Those which are of lowest organization, and (what seems of more importance) of lowest chemical character, as the gelatinous tissues, the areolar and tendinous, and the bones; (3). Those which are inserted in other tissues, not as essential to their structure, but as accessories, as

exercise, and that a weak galvanic current should be frequently transmitted through the limbs from the spine. This treatment has proved so far successful, that the progress of the disease appears to have been arrested in the most-advanced case, whilst a marked improvement has taken place in the condition of a younger child, who was previously passing rapidly into a state resembling that of his elder brothers.

* "Physiological, Anatomical, and Pathological Researches," p. 10.

† "Lectures on Surgical Pathology," vol. i., p. 106.

‡ See "Princ. of Comp. Phys.," Chap. xi., Sect. 3.

§ Op. cit., p. 164.

connecting or incorporating them with the other structures of vegetative or animal life, such as nerve-fibres or blood-vessels. With these exceptions, injuries or losses are capable of no more than repair in its limited sense; i. e. in the place of what is lost, some lowly-organized tissue is formed, which fills up the breach, and suffices for the maintenance of a less perfect life."—Yet, even thus restricted, the operations of this power are frequently most remarkable; and are in no instance, perhaps, more strikingly displayed, than in the re-formation and remodelling of an entire Bone, when the original one has been destroyed by disease. That this power is intimately related to that by which the organism is normally built-up and maintained, is evident, not merely from the peculiar mode in which it is exercised,—its tendency being always to reproduce each part in the form and structure characteristic of it at the particular period of life, and not according to its embryonic type,—but also from the fact that it is more effectual in the state of growth than in the adult condition, and that it can do far more in the embryonic state, when development as well as growth is taking place, than after the developmental process has ceased. In fact, as Mr. Paget has remarked (loc. cit.), its amount at different periods of existence, as in different classes of animals, seems to bear an inverse ratio to the degree of development which has already taken place. Thus it is well known to every Practitioner, how much more readily and perfectly the lesions resulting from accident or disease are repaired in childhood and youth, than they are after the attainment of the adult state. And there is evidence that during embryonic life, the regeneration of lost parts may take place in a degree to which we have scarcely any parallel after birth: for Prof. Simpson has brought-together numerous cases, in which, after 'spontaneous amputation' of the limbs of a fœtus, occurring at an early period of gestation, there has obviously been an imperfect attempt at the re-formation of the amputated part from the stump;* and it seems probable, from the history of normal development, that in the cases in which perfect hands and feet have been present without the corresponding limbs, these hands and feet have been secondary productions from the stumps of amputated limbs, since any original defect of development would have affected the hands and feet rather than the arms and legs. There are occasional examples, moreover, in which this regenerative power has been prolonged to an unusually late period; thus an instance is recorded, on authority that can scarcely be doubted, of the twice-repeated reproduction of a supernumerary thumb, after it had been twice completely removed;† and the Author has been assured by a very intelligent Surgeon, that he was cognizant of a case in which, the whole of one ramus of the lower jaw having been lost by disease in a young girl, the jaw had been completely regenerated, and teeth were developed and occupied their normal situations in it.

360. It has been a general opinion among British surgeons (founded

* These cases were brought by Prof. Simpson before the Physiological Section of the British Association, at its Meeting in Edinburgh, Aug 1850. The Author, having had the opportunity of examining two living examples, as well as Prof. Simpson's preparations, is perfectly satisfied as to the fact.

† See Mr White's Treatise on the "Regeneration of Animal and Vegetable Substances," (1785) p 16

upon what they believe, but erroneously, to have been the doctrine of Hunter), that Inflammation is essential to the process of Reparation. There is no doubt that, as usually conducted, the healing of wounds is attended by a greater or less degree of Inflammation; but it does not thence follow that this morbid condition is essential to the renewal of the healthy state; and in fact it can be shown that, in the majority of cases, the occurrence of Inflammation is injurious rather than beneficial. It was by Dr. Macartney, that the first clear enunciation of this important truth was made, and his conclusions, founded upon a philosophical comparative survey of the operations of Reparation and Inflammation, as performed in the different classes of animals,—namely, "that the powers of reparation and reproduction are in proportion to the indisposition or incapacity for inflammation,—that inflammation is so far from being necessary to the reparation of parts, that, in proportion as it exists, the latter is impeded, retarded, or prevented,—that, when inflammation does not exist, the reparative power is equal to the original tendency to produce and maintain organic form and structure;—and that it then becomes a natural function, like the growth of the individual, or the reproduction of the species," * —may be regarded as substantially correct, although requiring some modification in particular cases.

361. The simplest of all the methods of healing of an open wound is that which is termed by Dr. Macartney 'immediate union.' It is often seen in the case of small incised wounds, such as cuts of the fingers or the incision made in venesection, in which the two edges can be brought into close approximation, so that they grow together without any connecting medium of blood or lymph; but it sometimes occurs in larger ones,† and as it is the best imaginable process, the surgeon ought to favour it as much as possible, by procuring the most exact coaptation of the wounded parts, and by repressing any tendency to inflammation which will interfere with it. This is the mode of union which was spoken of by John Hunter as 'healing by the first intention.' He supposed that the union takes place through the medium of the blood intervening between the lips of the wound, which undergoes organization into a connecting tissue; but it is now certain that although blood may become organized, especially when effused into a wound secluded from the air, yet that its intervention opposes, rather than favours, healing by immediate union.

362. That which is commonly known amongst British Surgeons as 'healing by the first intention,' is that which was designated by Hunter as 'union by adhesion' or by 'adhesive inflammation.' This process takes place in the case of incised wounds, of which the edges are not brought into perfect coaptation, or in which some inflammatory action is present, which gives rise to the effusion of plastic lymph. In either case, the connection is finally re-established by the organization of the lymph, into which vessels pass from both surfaces; but the intervention

* Dr. Macartney's "Treatise on Inflammation," p. 7.

† Mr. Paget mentions a case of extirpation of a mammary tumour, in which the greater part of the wound was found to have healed after this fashion, the skin and fascia having so firmly adhered, that no indication existed of their previous detachment, and no effusion of coagulable lymph, or production of a connecting tissue, being detectable by microscopic examination. ("Lectures on Surgical Pathology," vol. i. p. 193.)

of this bond is manifested in the persistence of the cicatrix, which is quite distinguishable by its peculiar appearance from the surrounding tissue. A very good example of this process, as it takes-place under favourable circumstances, is presented after operations for hare-lip: the wound left by which, however, may partly heal by 'immediate union.' Even the moderate effusion of lymph, to a degree that is altogether salutary, cannot be regarded as alone sufficing, under such circumstances, to constitute Inflammation. But it is well known that if a slight wound, which is thus healing, be provoked to an increased degree of inflammation, its progress is interrupted; and all the means which the Surgeon employs to promote union, are such as tend to prevent the accession of this state.—The only case in which the concurrence of Inflammation can be regarded as salutary, is that in which there is a deficiency of Fibrin in the blood, causing a deficient *organizability* of the lymph. It has been seen that the amount of fibrin is rapidly increased by inflammation (§ 188): and the Surgeon well knows that a wound with pale flabby edges, in a depressed state of the system, will not heal, until some degree of Inflammation has commenced. But when the inflammatory state has developed itself, in however trifling a degree, there is always a risk of its proceeding further, and occasioning a degeneration of the plastic material, so that the formation of pus-cells and the effusion of purulent fluid take place, instead of the development of uniting tissue.

363. The reparation of wounds, in which there has been so great a loss of substance that neither immediate union nor adhesion by a thin layer of coagulable lymph can take place, is accomplished by the gradual development of new tissue from the 'nucleated blastema' with which the cavity is first filled. But this may take place in different modes, according to the degree in which it is disturbed by the Inflammatory process; and it should be the great object of the Surgeon, to procure the most favourable method of its performance. It has been shown by Mr Paget (Op. cit.), that the mode in which the process of filling-up is accomplished, differs essentially according as the wound is subcutaneous, or is exposed to air. In the former case, the nucleated blastema is gradually developed into fibrous tissues without any loss, and usually with freedom from local inflammation (beyond what may have been requisite for the production of the plastic fluid), as well as from constitutional irritation. In the latter case, the nucleated blastema is developed into cells; and those on its exposed surface are unable, either from degeneration or from imperfect development, to pass-on to any higher form of organization, but take-on the characters of pus-cells, and are only fit to be cast-off. Hence there is a continual loss of plastic material, the amount of which, in the case of an extensive suppurating sore, forms a most serious drain upon the system; whilst, at the same time, the local inflammation gives-rise to more or less of constitutional disturbance, and the formation of new tissue is by no means so perfect as in the preceding case. In cold-blooded animals, however, the contact of air does not produce this disturbance, and we see wounds with extensive loss of substance gradually filled-up in them by the development of new tissue, without any suppuration or other waste of material, very much as in the subcutaneous wounds of warm-blooded animals. This method of healing, which has been termed by Dr. Macartney the 'modelling process,' is nothing else than healing by granulations

under the most favourable circumstances; and to procure this should be the endeavour of the Surgeon, who too frequently considers suppurative granulation as the only means by which an open wound can be healed up. The difference between the two modes of reparation is often one of life and death, especially in the case of large burns on the trunk in children; for it frequently happens that the patient sinks under the great constitutional disturbance occasioned by a large suppurating surface, although he has survived the immediate shock of the injury.—Now the means adopted by Nature to bring this about, in warm-blooded animals, is the formation of a *scab;* which reduces the wound more nearly to the condition of a subcutaneous one, so that the reparative growth and formation of new tissue take place (under favourable circumstances) without any suppuration, and with scarcely any irritation; the subsequent cicatrix, too, being much more like the natural parts, than are any scars formed in wounds that remain exposed to the air. In the Human subject, however, the process is far less certain than it is among the lower animals, owing to the liability to inflammation in the wounded part, and the consequent effusion of fluid, which produces pain, compresses the wounded surface, or forces off the scab, with great discomfort to the patient, and retardation of the healing. Small wounds, however, in persons of good habit of body, and in parts which can be completely kept at rest, readily heal in this manner; and large wounds have been known to close, in the same desirable mode, beneath a clot of inspissated blood. In fact, among 'uncivilized' nations whose habits of life are favourable to health,—their bodies being continually exposed to fresh air, their food wholesome and taken in moderation, and their drink water or other unstimulating liquids,—there seems to be as great a tendency to this method of reparation, as exists among the lower animals; and the difficulty of procuring it among the members of 'civilized' communities, is owing, without doubt, to the *unnatural* conditions under which they too frequently live. Seeing as we continually do the effects of foul air, of habitual excess in diet, and of the constant abuse of stimulants, in impairing that form of the reparative process which must be regarded as the *least* favourable, namely, the closure of a wound by suppurating granulations, it is very easy to comprehend, that, to induce the *most* favourable method, the most perfect freedom from all pernicious agencies should be required.

364. The most effectual means of promoting this kind of Reparative process, and of preventing the interference of Inflammation, vary according to the nature of the injury. The exclusion of air from the surface, and the regulation of the temperature, appear the two points of chief importance. By Dr Macartney, the constant application of moisture is also insisted-on.* He states that the immediate effects of injuries, especially of such as act severely upon the sentient extremities of the nerves, are best abated by the action of "*steam* at a high but comfortable temperature, the influence of which is gently stimulant, and at the same time extremely soothing." After the pain and sense of injury have passed away, the steam, at a lower temperature, may be continued; and, according to Dr. M., no local application can compete with this, when the Inflammation is of an active character. For subsequently restraining this, however, so as to promote the simple reparative process, Water-

* "Treatise on Inflammation," p. 178

dressing will, he considers, answer sufficiently well; its principal object being the constant production of a moderate degree of Cold, which diminishes, whilst it does not extinguish, sensibility and vascular action, and allows the Reparative process to be carried-on as in the inferior tribes of animals. The reduction of the heat in an extreme degree, as by the application of ice or iced water, is not here called-for, and would be positively injurious; since it not only renders the existence of Inflammation in the part impossible, but, being a direct sedative to all vital activity, suspends also the process of restoration. The efficacy of Water-dressing in injuries of the severest character, and in those which are most likely to be attended with violent Inflammation (especially wounds of the large joints) has now been established beyond all question; and its employment is continually becoming more general.*—Other plans have been proposed, however, which seem in particular cases to be equally effectual. To Dr. Greenhow, of Newcastle, for instance, it was accidentally suggested, a few years since,† to cover the surface of recent burns with a liquefied resinous ointment, so as to form an artificial scab; and he states that in this manner suppuration may be prevented, even where large sloughs are formed; the hollow being gradually filled-up by new tissue, which is so like that which has been destroyed, that no change in the surface manifests itself, and none of that contraction, which ordinarily occurs even under the best management, subsequently takes place.—A plan has, moreover, been proposed for preventing suppuration and promoting reparation by the 'modelling' process, which consists in the application of *warm dry air* to the wounded surface. Although the experiments yet published have not been entirely satisfactory, they seem to show that, whilst the process of healing may be slower under treatment of this kind, it is attended with less constitutional disturbance than is often unavoidable in the ordinary method; and, that it may, therefore, be advantageously put in practice in those cases, in which the condition of the patient requires every precaution against such an additional burthen,—as after amputation in a strumous subject.‡

365. When the process of healing of an open wound by Suppurative Granulation is attentively watched, it is seen that the first stage is the formation of a 'glazing' on the exposed surface, which closely resembles the buffy coat of the blood, being composed of coagulated fibrin and colourless corpuscles; in this manner a sort of imperfect epithelium may be formed, within half an hour after the surface has been laid-bare. The increase of this glazing is the prelude to the formation of granulations; but whilst it is going-on, there is, in and about the wound, an appearance of complete inaction, a sort of calm, in which scarcely anything appears except a slight oozing of serous fluids from the wound, and which continues from one day to eight, ten, or more, according to the nature and extent of the wounded part, and the general condition of the body. "This calm," says Mr. Paget, "may be the brooding time for either good or evil; whilst it lasts, the mode of union of the wound will, in many cases, be determined; the healing may be perfected, or a slow uncertain process

* See an account of the results of this treatment by Dr. Gilchrist, in "Brit. and For. Med. Rev.," July 1846, p. 242.

† "Medical Gazette," Oct. 13, 1838.

‡ See M. Jules Guyot "De l'emploi de la Chaleur dans le Traitement des Ulcères, &c."

of repair may be but just begun; and the mutual influence which the injury and the patient's constitution are to exercise on one another, appears to be manifested more often at or near the end of this period, than at any other time." The cessation of this period of calm, and the active commencement of the reparative operations, are marked by the restoration of the flow of blood in the vessels of the wounded part; but the current is not altogether normal, being slower but fuller than natural, so that on the whole more blood than usual passes through the capillary plexus. This increased afflux of blood is followed by effusion of plastic material in increased proportion; and it is from this effusion, that the granulating process properly commences.—The plastic material effused upon the surface of an *open* wound, is first developed into cells; and these cells, in the deeper portions of the effusion, are metamorphosed into fibrous tissue, of which the substance of the granulations is composed. Those which are formed upon the surface, however, are converted into pus-cells (§ 375); in some instances (as Mr. Paget has pointed out) by degeneration from a higher development; in other cases by an originally imperfect development: and thus the granulation surface is constantly in a state of morbid action, and a large proportion of the plastic material is completely wasted. The layer of pus, however, serves as a sort of epithelium for the subjacent granulation-tissue, in which we find not only a complete formation of cells, but a commencement of the metamorphosis of these cells into fibres, before blood-vessels make their appearance in the tissue. These blood-vessels are formed by "out-growth" from the subjacent capillaries, in the mode elsewhere described (PRINC. OF GEN. PHYS.). From the investigations of Mr. Liston, it appears that the vessels of the subjacent tissue are much enlarged, and assume a varicose character. The bright red colour of the granulations, however, does not depend on their vascularity alone; for the cells themselves, especially those most recently evolved, are of nearly as deep a colour as the blood corpuscles; and the sanguineous exudation which follows even the slightest touch of the granulating surface, does not proceed from blood effused from the newly formed vessels only; for the red fluid shed in this manner contains, besides blood-discs, newly-developed red cells, nuclei, cytoblasts, pale granules, and reddish serum. It is a common property of animal cytoblasts, that they present a reddish colour on their first formation, when in contact with oxygen; but this hue they lose again, whether they advance to perfect development and become integral parts of a living tissue, or die and degenerate.

366. The process of Suppurative Granulation, then, appears to differ from the process of granulation as it takes place in *closed* wounds, or in a warm moist atmosphere (the 'modelling-process' of Dr. Macartney), essentially in this:—that a large part of the exudation-corpuscles deposited on the wounded surface degenerate into pus in the former case, whilst none are thus wasted in the latter;—but that the existence of inflammation occasions a more copious supply of fibrin in the former case, and increases its tendency to become organized; the filling-up of a wound with granulations being thus a much more rapid process, than that renewal of the completely-formed tissues, which may take place in the absence of inflammation. The imperfect character of the granulation-structure is shown, by the almost complete disappearance of it after the wound has

closed-over. The portion of it in immediate contact with the subjacent tissue, however, appears to undergo a higher organization; for it becomes the medium by which the cicatrix is made to adhere to the bottom of the wound. It is very liable to undergo changes which end in its disintegration; as is evident from the known tendency to re-opening, in wounds that have been closed in this manner.

367. When two opposite surfaces of granulations, well developed, but not yet covered with cuticle, are brought into apposition, they have a tendency to unite, like the two original surfaces of an incised wound. This method of union, which was noticed by John Hunter, has been appropriately termed 'secondary adhesion' by Mr. Paget. The surgeon may frequently have recourse to it with great advantage, when primary adhesion is impossible, and when the filling-up of the wound with granulations would be a tedious process, and very exhausting to the patient. In applying it to practice, it is essential to success, first, that the granulations should be healthy, not inflamed or profusely secreting, nor degenerated as those in sinuses commonly are; and secondly, that the contact between them should be gentle but maintained: it seems desirable, also, that the granulation-surfaces should be as much as possible of equal development, and alike in character.*

3.—*Abnormal Forms of the Nutritive Process.*

368. Under the preceding head, we have considered the chief variations in the degree of activity that are witnessed in the ordinary or normal conditions of the Nutritive process,—those conditions, namely, in which the products are adapted, by their similarity of character, to replace those which have been removed by disintegration. But we have now to consider those forms of this process, in which the products are *abnormal*,—being different from the tissues they ought to replace. We shall confine ourselves to a brief examination of a few of some of the most important of these states; and that which first claims our consideration, on account of the frequency of its occurrence and the importance of its results, is *Inflammation.*—Although Pathologists have been accustomed to look for the 'proximate cause' of the phenomena which essentially constitute the Inflammatory state, or, in other words, for the first departure from the normal course of vital action, in the enlarged or contracted dimensions of the blood-vessels of the inflamed part, or in the altered rate of movement of the blood through it, yet it may now be safely affirmed that these are only secondary alterations, depending upon an original and essential perversion of that normal reaction between the blood and the tissues, which constitutes the proper Nutritive process. This perversion manifests itself (1) in a diminution in the formative activity of the tissues, leading to their degeneration and death; (2) in a tendency to augmented production of the plastic components of the blood; and (3) in the effusion of these components, either in a state in which they may pass into a low form of organized tissue, or in such a degraded condition that they are altogether unorganizable, and are fit only to be cast-out from the body. Each of these

* On the whole subject of the Reparative Processes, see Mr. Paget's admirable "Lectures on Surgical Pathology" (vol. i., Lect. vii. xii.); from which many of the foregoing statements and doctrines are adopted.

phenomena requires a separate examination, both as to its causes and its consequences.

369. Although it has been customary to speak of Inflammation as a state of 'increased action' in the part affected,—of which increased action, the augmentation in the bulk and weight of an inflamed part, and in the quantity of blood which passes through it, together with its higher temperature and more acute sensibility, would seem to furnish sufficient evidence,—yet all these signs are found to be deceptive, when they are more closely examined; and the conclusion is forced upon us, that the vital power of the part is really *depressed* rather than exalted. For the increase in bulk and weight is not due to such an augmentation of its proper tissue, as would truly constitute Hypertrophy; on the contrary, even in the slightest forms of Inflammation there is such a diminution in the rate of its nutrition, as really constitutes Atrophy, and such augmentation of the solid mass as may take place, is produced by the passage of the effused fluid into an organized tissue of the lowest kind, and this in virtue rather of its own plasticity, than of the vital force which it derives from the tissues which it infiltrates. That there has been an atrophy rather than a hypertrophy of the proper fabric of the part, becomes evident enough when the inflammation has passed-away, and this newly-formed tissue undergoes degeneration and absorption. The only tissues in which there is any appearance of increased formation during the inflammatory state, are those which correspond in their low type of organization with the new tissue thus generated: namely, the areolar and other simple fibrous tissues, and also the osseous, of which the organized basis is somewhat of the same kind. When the Inflammation is more severe, the tendency to degeneration in the proper tissues of the part becomes very obvious: for it is by their *interstitial* decay and removal that the cavity of an *abscess* is formed; it is by their *superficial* death and absorption or solution, that *ulceration* takes place, and it is in the death of a whole mass at once, that *gangrene* consists.

370. That a diminution in the formative activity of the Tissues is an essential characteristic of the Inflammatory state, further appears from the study of its Etiology; for whether the causes to which the inflammatory attack may be traced are *local* or *general*, acting primarily upon the tissues of the part, or first affecting the blood, their operation is essentially the same. Thus the *local* causes are all obviously such, as tend either directly to depress the vital powers, or to elevate them at first, and then to depress them by exhaustion. Of the former kind are cold and mechanical injury; also many chemical agents, whose operation tends to bring back the living tissues to the condition of inorganic compounds. Under the latter category are to be ranked all those agencies, which produce over-exertion of the functional power of the part; amongst which may be named heat, when not so excessive as to produce a directly destructive effect. Now cold, heat, chemical agents, and mechanical injury, when operating in sufficient intensity, at once *kill* the part, by entirely destroying, instead of merely depressing, its vital powers; and it is on the borders of the dead part, where the cause has acted with less potency, that we find the inflammatory state subsequently presenting itself.—On the other hand, there can be no doubt that many inflammations have their origin in morbid conditions of the Blood, which, without any other

cause whatever, may determine all the other phenomena. This is most obvious with regard to those of a 'specific' kind; but it is also probably true of the majority of the so-called spontaneous or constitutional, as distinguished from traumatic inflammations. We seem, indeed, to be able to trace a regular gradation, between inflammatory attacks which are entirely traceable to the introduction of a poison into the blood, and those which result from causes purely local. Under the first head, we may unquestionably rank such inflammatory diseases as are produceable by inoculation, the eruptive fevers for example; and scarcely less thoroughly demonstrated are the cases of rheumatism and gout, and many inflammations of the cutaneous textures, which, when occurring in the chronic form, tend to exhibit a regular symmetry (§ 217). In all such cases, the local affections are the external signs of the general affection of the blood, just as are the inflammations produced by the introduction of arsenic or of other irritant poisons into the circulation; and they may in fact be reasonably attributed to the impairment of the formative activity of the parts upon which these poisons fix themselves, in virtue of their 'elective affinity' (§ 223), just as the peculiar functional activity of the nervous centres is affected by narcotic poisons. And this view of the really-local action of what are primarily regarded as general or constitutional causes of inflammation, is confirmed by the fact, that the localization of the perverted nutritive condition is often determined (as both Dr. W. Budd and Mr. Paget have remarked) by a previous or concurrent weakening or depression of the vital activity of the part. Thus a part which has been the seat of former disease or injury, and which has never recovered its vigour of nutrition, is always more liable than another to be the seat of local manifestation of blood-disease; it is, in common language, the 'weak part.'* And it frequently needs such a concurrent operation of a local depressing cause, to fix and develope the action of the constitutional cause, or blood-disorder; thus, a rheumatic or gouty diathesis may exist for some time (as when, to use a common expression, the disease is 'flying about' the patient), and yet the poison may not have sufficient potency to produce an attack of acute inflammation, until the vitality of some particular organ becomes depressed by cold, over-exertion, or some similar influence, which would not have itself engendered the diseased action, had it not been for the concurrence of the morbid condition of the blood. Thus we seem justified in concluding, that, whether the causes of Inflammation act directly upon the tissues of a part, or whether they act upon it through the intermediation of the blood, their effect is to produce a depression in its vital powers, which manifests itself in *a deficient formative activity*, and in *an increased tendency to degeneration;* and that this is one of the primary and essential conditions of Inflammation.

371. This view is by no means inconsistent with the occurrence of other manifestations of Inflammation, which have been supposed to indicate 'increased action;' and, in fact, it is in such striking accordance with

* Thus Impetigo appears about blows and scratches in unhealthy children, and Erysipelas first attacks the seat of local injury in men with unhealthy blood. Perhaps as good an example as any, is afforded by the uniform limitation of the inflammation consequent upon the introduction of Vaccine matter into the blood, to the spots in which the puncture was made, notwithstanding that the whole mass of blood is affected by it, as is shown by its incapacity for subsequently developing the poison of small pox. See also § 231.

the phenomena presented by the movement of the blood, when these are interpreted by the principles already laid-down, as to afford a powerful confirmation to both doctrines. The usual condition of the vessels of an inflamed part, is one of dilatation; and this may be fairly attributed to the lowered vitality of their walls, whereby they yield too readily to the distending force of the current of blood. But this current moves too slowly; and its retardation may gradually increase, in the part most intensely inflamed, to the point of complete stagnation. Now this altered rate of movement cannot be attributed to any general cause; nor can it be accounted-for by the change in the diameter of the vessels; for, on the one hand, it may occur with a constricted state of the vessels, whilst, on the other, in the vessels surrounding the inflamed part, which partake of the dilated condition, the flow of blood is so far from being retarded, that it usually takes-place more rapidly than usual. But it may be fairly considered as the result of the lowered or suspended nutritive activity of the part, which will tend to retard or entirely check the motion of blood in the systemic capillaries, just as the want of aeration retards or checks the pulmonary circulation (§ 272). It is quite true that a larger amount of blood passes through a limb, of which *some part* is in a state of active inflammation, than passes through the corresponding sound limb; but this is far from indicating 'increased action' in the inflamed part, being dependent upon the augmented flow of blood through the tissues which surround it; and if *the whole* of a limb be in a state of inflammation passing on to gangrene (as occurs when a 'frost-bitten' limb has been incautiously warmed), the amount of blood which passes through it is diminished.—It would be just as erroneous to assume the elevated temperature of an inflamed part as a sign of 'increased action' in it; for this elevation is no doubt attributable in part to the augmented flow of blood through the surrounding vessels; and, so far as it depends upon local changes, it obviously indicates a more rapid disintegration of tissue, rather than a more energetic production of it; since it is in the former state, rather than in the latter, that the conditions of the development of heat (on the chemical theory) are supplied, as we see that the heat of a muscle is the greatest when it is being disintegrated by active exercise, not when it is being repaired by the formation of new tissue in the intervals of repose. But, as Mr. Paget justly remarks, "this phenomenon is involved in the same difficulty as are all those that concern the local variations of temperature in the body; difficulties which the doctrines of Liebig, however good for the general production of heat, are quite unable to explain." (See Chap. x.)—And lastly, with regard to the unusual tenderness of inflamed parts, this is obviously due to such a combination of causes, neither of which can be legitimately held to indicate an increase of its proper vital activity, that nothing can be rested on this alone; especially as we see an augmentation in the susceptibility of the sentient nerves, under many circumstances (as in hysterical disorders), in which, far from an *augmented*, there is obviously a *diminished* activity in the parts from which they spring.—That neither an alteration in the circulation of a part, nor a departure from the normal condition of its nervous supply, can be regarded as one of the essential phenomena of inflammation, is obvious from this, that the most important phenomena of inflammation may present themselves, as results of injury or disease, in parts

that have neither blood-vessels nor nerves: this is seen in the deposition of lymph in the cornea, in the ulceration of the cornea and of articular cartilages, and in other morbid actions in these parts, which, if ever they are vascular, become so only after the effusion of lymph in them, the new vessels being formed in this lymph, and not in the tissues themselves. Here it is obvious that the whole change consists in a perversion of the nutritive actions which the tissues ought to carry-on, at the expense of the materials which they draw from the blood of the surrounding vessels.

372. Of the alterations in the condition of the *Blood* in Inflammation, an account has already been given (§§ 187—191); and it is here only necessary to recapitulate them. The most characteristic is the augmentation, either of the organizable or plastic fibrin, or of the organized colourless corpuscles; the increased production of these two components seeming to bear in some degree a relation of reciprocity, the one to the other. The increase of Fibrin may be considered as the alteration most characteristic of a previously-healthy and vigorous state of the system, and it is in the inflammations which occur in such subjects, that the effusions are most strongly disposed to become organized, and show the least tendency to undergo degenerative changes. On the other hand, the increase of the Corpuscular element seems to occur in cachectic or otherwise unhealthy individuals; and the inflammatory effusions which partake of the same character, are far less plastic originally, and are extremely prone to undergo degeneration, either at the time of their effusion, or subsequently. With this increase in the proportion of fibrin and colourless corpuscles, separately or in combination, there is a diminution in the proportion of the red corpuscles, albumen, and salts of the blood. None of these changes, however, can be legitimately regarded as originally or essentially characteristic of the inflammatory condition; they are, in fact, to be looked-on rather as the results of its establishment, constituting that series of alterations in the circulating fluid, which is of parallel order to that which occurs in the solid tissues wherein the inflammatory action has been set-up.

373 The Inflammatory state is further characterized by the *effusion* of certain of the components of the Blood, upon the surface, or into the substance, of the inflamed tissues.—The effusion of pure *serum* cannot be regarded as characteristic of inflammation; since it may take-place as a mere result of congestion, especially when this congestion is due to an obstruction to the return of the blood; whilst, again, it may be due to an altered condition of the albuminous constituent of the blood, which favours its transudation (§ 183). The so-called serous effusions which are poured-forth in inflammation, do in reality contain fibrin in solution; but this fibrin may not manifest its presence by spontaneous coagulation, until its passage into the solid state is favoured by the introduction of a piece of the washed clot of blood, or of the buffy coat, or of muscle or some other animal tissue, which seems to act as a sort of nucleus of fibrillation. The presence even of fibrin in such an effusion, however, is not in itself a sufficient proof of the existence of inflammation; for it has been shown by the experiments of Mr. Robinson,* that when the obstruction to the return of blood by the veins is so great as to occasion

* "Medico-Chirurgical Transactions," vol. xxvi. p. 51.

an excessive pressure within the capillaries, the fluid which transudes may contain enough fibrin to render it spontaneously coagulable.—The form of exudation which is most characteristic of Inflammation, is that which is known as *coagulable lymph;* it is much to be desired, however, that some other designation should be applied to it, since the term 'lymph' can only be appropriately employed for the fluid contents of the lymphatic vessels. The peculiar characteristic of this inflammatory exudation, is its capability of spontaneously passing into the condition of an organized tissue, either fibrous or cellular, or a mixture of both, and of thus forming 'false membranes' on inflamed surfaces, or solidifying the inflamed part by the interstitial production of similar lowly-organized textures. Although it has been too much the habit of Pathologists, to speak of 'coagulable' or 'plastic lymph' as if it were always one and the same thing, yet it really presents various gradations of character, which are manifested in its different degrees of organizability, and in the diverse nature of the tissues developed from it, and, as Mr. Paget has pointed out,* there are two typical forms, the *fibrinous*, and the *corpuscular*, between which the others are intermediate. The former coagulates into a fibrous clot, resembling that of healthy blood, but usually showing a more distinct fibrillation. The latter (the 'croupous' exudation of Rokitansky) is characterized by the want of any proper coagulation, the fibrous clot being replaced by an aggregation of cells, which in their first appearance resemble very nearly the primordial condition of the corpuscles of the fluids of the absorbent vessels, and the colourless corpuscles of the blood. It is seldom, however, that either of these typical forms of lymph presents itself in a state of complete isolation from the other; they are much more commonly blended in various proportions, so that one or the other predominates; and it is mainly upon the preponderance of fibrin, that the 'plasticity' of the exudation (or its capacity for organization) depends; whilst according to the preponderance of corpuscles, will be its tendency to degeneration. Thus the exudation of fibrinous lymph is the symbol of the 'adhesive' inflammation, whilst that of the 'corpuscular' is similarly characteristic of the 'suppurative' inflammation.

374. It is obviously of great consequence to ascertain the conditions which determine the production of one or other of these states, and these, as Mr. Paget has remarked (loc. cit.), may be considered under three heads,—(1) the previous state of the blood, (2) the seat of the inflammation, and (3) the degree and character of the inflammation. The *condition of the blood*, as determining that of the lymph, has been carefully studied by Rokitansky, who has shown that the characters of inflammatory deposits in different diatheses, correspond very generally and closely with those of the coagula found in the heart and pulmonary vessels after death. The results of Mr Paget's experiments on the same subject have been already cited (§ 212). And clinical observation fully confirms this doctrine by evidence of another kind; that, namely, which is afforded by the different course of the same specific diseases, in different individuals, according to the previously healthy or abnormal condition of their blood. There can be no doubt that a very large proportion of what are called 'unhealthy inflammations,' especially those of the erysipelatous type, are to be regarded as owing their peculiarity to a

* "Lectures on Surgical Pathology," vol. i. p. 332.

deficiency in the due elaboration of the fibrin, and to the low vitality of the cellular components of the blood; both of which conditions seem to be favoured by the presence of those decomposing matters, whose accumulation in the blood acts in many ways so prejudicially on the system at large (§ 226).*—That the quality of the exudation is in some degree determined by the *seat* or *tissue* in which the Inflammation occurs, appears from the different character of the products of the disordered actions, that occur simultaneously in different organs of the same individual, and apparently under the operation of the same cause; thus it may happen that in pleuro-pneumonia, the two surfaces of the pleura become connected by an organized exudation of a fibrous character; whilst the effusion in the substance of the lung is rather of the corpuscular nature, and speedily passes into suppurative degeneration. Mr. Paget ingeniously proposes to account for the determining influence in question, on the idea that the inflammatory product is influenced at the time of its formation by the assimilative force of each part, so that it is to be regarded as a mixture of true lymph with its special product of assimilation; thus we observe that in inflammations of bone the lymph usually ossifies, in those of ligaments it is converted into a tough ligamentous tissue, and in those of secreting organs it contains a mixture of the ordinary secreted product.—The mode in which the *intensity* of the Inflammation affects the character of the effused lymph, is twofold. For, in the first place, the nature of the original effusion is likely to vary according to the degree in which the ordinary nutritive process is interrupted; since, the more intense the inflammation, the less will be the assimilating force of the part, and the more will the matters effused from the vessels deviate from the natural plasma which would be drawn from them in healthy nutrition; whilst on the other hand, when the inflammation is less severe, its product will not differ so widely from the natural one, and will from the first tend to manifest in its development some characters corresponding to those of the natural formations of the part. But, secondly, the influence of the inflammation, or rather of the depressed vitality of the inflamed tissues, is shown in the tendency to degeneration which it impresses on the exuded product; so that, even though this may be disposed to pass-on under favourable circumstances to the complete formation of an organized tissue, its development is early checked, and it undergoes retrograde metamorphosis; or else, from the very commencement, its development takes place according to a lower or degraded type. The normal product of the organization of either fibrinous or corpuscular lymph, is undoubtedly a tissue closely allied to the ordinary areolar or connective; it is of this that false membranes and adhesions are formed, and that the material of most thickenings and indurations of parts is composed;† and it is by the production of this tissue also, that losses of substance are in the first instance repaired, and that divided surfaces are made to adhere. Various kinds

* See Mr. Brooke Gallwey's papers on 'Unhealthy Inflammation,' in the "Lancet" for 1849-50, and the "Medical Gazette" for 1850-51.

† The Author is much disposed, however, to agree with Dr. Handfield Jones, in believing that a chronic 'fibroid degeneration,' resulting from the substitution of a lowly-organized fibrous tissue for the proper texture of the part, may take place, like 'tubercular degeneration' (§ 376), without the occurrence of Inflammation, properly so called. See "Brit. and For. Med.-Chir. Rev.," vol. xiii. pp. 343-349.

of degeneration may subsequently take place in any of these products, according to the stage at which the developmental process is checked; and among these, in tissues which have once attained an advanced stage of development, the most common is the fatty (§ 347).

375. But the most frequent of all the degenerations of lymph, being almost invariable when the lymph is placed *from the first* in conditions unfavourable to its development, is into the entirely unorganizable or *aplastic* product which is known as *Pus*. This, as already mentioned, is specially liable to occur in lymph which is originally rather corpuscular than fibrinous; and every gradation may be seen, from the most characteristic form of the lymph-cell, to that of the pus-cell. But it would seem as if even the most perfectly fibrinous lymph may pass almost immediately into the condition of pus, when it is effused among tissues which are passing rapidly into a state of decomposition; and thus it appears to be, that in a phlegmonous inflammation, the lymph effused into the parts where the inflammatory process has been most intense (the stagnation of the blood being the most complete, and the normal tissues most disposed to disintegration), does not present the slightest tendency to a higher type of organization, but is developed from the first in the condition of pus, which fills the vacant space previously occupied by living tissue; whilst, in the surrounding parts, the fibrinous effusion produces a consolidation of the tissue, and thus forms the walls of the abscess, by which the purulent effusion is limited. Whether the disintegrating tissues are entirely removed by absorption (having previously undergone that degenerative softening which is requisite for the occurrence of this process), or whether they are broken-up and dissolved in the purulent fluid, is a point not yet determined.—The *conservative* nature of the fibrinous exudation, and the consequent importance of fibrin as an element of it, are well shown by the results of its deficiency. Thus if there be no 'sac' formed around a collection of pus, this fluid infiltrates through the tissues, and by its mere presence so impairs their nutrition, that a corresponding degradation takes place in the characters of the plastic material furnished for their assimilation; and hence the purulent effusion spreads without limit, and the tissues through which it percolates undergo rapid degeneration. So, again, when gangrene is spreading by contiguity (the proximity of the dead tissue tending to lower the vitality, and even to occasion the death, of that with which it is continuous), it is only when an inflammatory 'reaction' takes place, or, in other words, when an exudation of fibrinous lymph is poured into the substance of the tissues bordering on those which have lost their vitality, that a line of demarcation between the dead and the living parts is formed. And generally it may be said, that, as the ultimate tendency of Inflammation is to produce the disintegration of the part, the ultimate tendency of the fibrinous exudation is to keep its elements together, and to repair the losses which have taken place, although with a very inferior material. It is only, however, with the subsidence of the inflammation, and the return to the ordinary type of nutrition, that the highest development of the lymph can take place; and it is in proportion as this occurs more speedily, that the recovery of the organization proper to the part is more completely effected.*

* The Author has pleasure in referring to Mr. Paget's "Lectures on Surgical Pathology"

376. In persons of that peculiar constitution, which is termed *Scrofulous* or *Strumous*, we find an imperfectly-organizable or *caco-plastic* deposit, or even an altogether *aplastic* product, known by the designation of *Tubercular* matter, frequently taking the place of the normal elements of tissue; both in the ordinary process of Nutrition, and still more when Inflammation is set-up. From an examination of the Blood of tuberculous subjects, it appears that although the bulk of the coagulum obtained by stirring or beating it is usually greater than that of healthy blood, yet this coagulum is not composed of well-elaborated Fibrine; for it is soft and loose, and contains an unusually-large number of Colourless corpuscles, whilst the Red corpuscles form an abnormally-small proportion of it. We can understand, therefore, that such a constant deficiency in plasticity must affect the ordinary nutritive process; and that there will be a liability to the deposit of cacoplastic products, instead of the normal elements of tissue, even without inflammation. Such appears to be the history of the formation of Tubercles in the lungs and other organs, when it occurs as a kind of metamorphosis of the ordinary Nutritive process, and in this manner it may proceed insidiously for a long period, so that a large part of the tissue of the lungs shall be replaced by tubercular deposit, without any other ostensible sign than an increasing difficulty of respiration. In the different forms of tubercular deposit, we see the gradation most strikingly displayed, between the plastic and the aplastic formations. In the semi-transparent, miliary, grey, and tough yellow forms of Tubercle, we find traces of organization in the form of cells and fibres, more or less obvious, these being sometimes almost as perfectly formed as those of plastic lymph, at least on the superficial part of the deposit, which is in immediate relation with the living structures around, whilst they may be so degenerated, as scarcely to be distinguishable. In no instances do such deposits ever undergo further organization; and therefore they must be regarded as *caco-plastic*. But in the opaque, crude, or yellow Tubercle, we do not find even these traces of definite structure; for the matter of which it consists is altogether granular, more resembling that which we find in an albuminous coagulum. This is entirely *aplastic*. The larger the proportion of this kind of matter in a tubercular deposit, the more is it prone to *soften;* whilst the semi-organized tubercle has more tendency to *contraction*.—It may be questioned, however, whether Tubercular matter is not always, even in its most amorphous state, a product of cell-formation; and whether the difference between the amount of organization which its several forms present, is not due rather to a variation in the degree of its subsequent degeneration, than to an original diversity in histological condition. On this view, Tubercle is to be considered as a formation *sui generis*, whose production is dependent upon a special taint in the blood, and just as the normal lymph-products vary greatly in their degree of vitality, so that some undergo a progressive and others a retrograde metamorphosis, so may tubercular deposits either retain their original

(vol. i.), as containing, in his opinion, the best exposition of the subject of Inflammation yet made public; and in acknowledging his obligations to them for much assistance in the short view of it given above. The fundamental doctrines on which the Author would lay the greatest stress, however, are the same in all essential particulars with those which he taught in the earlier Editions of this Treatise.

characters more or less completely (though never advancing towards a higher type), or may undergo a very early and complete degeneration.*

377. But although Tubercular matter may be slowly and insidiously deposited, by a kind of degradation of the ordinary Nutritive process, yet it cannot be doubted that Inflammation has a great tendency to favour it, so that a larger quantity may be produced in the lungs, after a Pneumonia has existed for a day or two, than it would have required years to generate in the previous mode. But the character of the deposit still remains the same; and its relation to the plastic element of the blood is shown by the interesting fact, of no unfrequent occurrence,—that, in a Pneumonia affecting a tuberculous subject, plastic lymph is often thrown out in one part, whilst tubercular matter is deposited in another. Now Inflammation, producing a rapid deposition of tubercular matter, is peculiarly liable to arise in organs, which have been previously affected with chronic tubercular deposits, by an impairment of the process of textural Nutrition; for these deposits, acting like foreign bodies, may of themselves become sources of irritation; and the perversion of the structure and functions of the part renders it peculiarly susceptible of the influence of external morbific causes.

378. We frequently meet with abnormal growths of a Fatty, Cartilaginous, Fibrous, or even Bony structure; which result from the development of these tissues in unusual situations, and appear to originate in some perverted action of the parts themselves (§§ 353, 374 *note*).—But there is another remarkable form of disordered Nutrition, which is concerned in producing what have been termed *heterologous* growths; that is, masses of tissue that differ in character from any which is normally present in the body. Most of these are included under the general designation of *Cancerous* or *Fungous* structures; and it has been shown by Müller and succeeding inquirers, that the new growth consists of a mass of cells which, like the Vegetable Fungi, develope themselves with great rapidity, and which destroy the surrounding tissues by their pressure, as well as by abstracting from the Blood the nourishment which was destined for them. These parasitic masses have a completely independent power of growth and reproduction; and some kinds of them can be propagated by inoculation, which conveys into the tissues of the animal operated on, the germs of the peculiar cells that constitute the morbid growth, these soon developing themselves into a new mass. So it may be by the diffusion of the germs produced in one part, through the whole fabric, by means of the circulating current, that the tendency to re-appearance (which is one great feature in the *malignant* character of these diseases) is occasioned. But it would seem more probable, that this character rather depends upon the presence of a morbid matter in the blood, of which the formation of the Cancerous tissue is only the manifestation (§ 340 *note*); the local disease thus being the consequence of a constitutional cachexia, rather than the constitutional affection the result of the local disease.†

* See Mr. Paget in the "Pathological Catalogue of the Hunterian Museum," vol. i, p. 134; also Dr. Madden's "Thoughts on Pulmonary Consumption."

† See Dr. Walshe on "The Nature and Treatment of Cancer;" Mr. Simon's "General Pathology," Lect. viii; and Mr. Paget's "Lectures on Surgical Pathology," vol. ii, Lect. xiv.

CHAPTER IX.

OF SECRETION AND EXCRETION.

1. *Of Secretion in General.*

379. THE literal meaning of the term Secretion is *separation;* and this is nearly its true acceptation in Physiology. But the ordinary processes of Nutrition involve a separation of certain of the components of the Blood, which are withdrawn from it by the appropriating power of the solid textures; and every such removal may be considered in the light of an act of *excretion*, so far as the blood and the rest of the organism are concerned (§ 217). Moreover, the separation of certain matters from the blood in a fluid state, either for the purpose of being cast-forth from the body or of being employed for some special purpose within it, which constitutes what is ordinarily known as Secretion, is effected by an instrumentality of the same nature with that whose operation constitutes an essential part of the nutritive process; namely, the production and subsequent agency of cells. Hence there is no other fundamental difference between the two processes, than such as arises out of the diverse *destinations* of the separated matters, and from the anatomical arrangements which respectively minister to these. For the products of the Secreting action are all poured-forth, either upon the external surface of the body, or upon the lining of some of the cavities which communicate with it; and the cells by which they are separated from the blood, usually stand in the relation of epithelium cells to those prolongations of the skin or of mucous membranes, that form the follicles or extended tubuli of which the Glandular organs are for the most part composed (Figs. 55, 66). The act of Secretion appears to consist, in some cases, in the successive production and exuviation of the cells which minister to it, these cells giving up, by rupture or deliquescence, the substances which they have eliminated from the blood; such, for example, appears to be the mode of separation of the Sebaceous secretion of the skin, of the Mucous secretion of mucous membranes, of the secretion of Milk, and perhaps also of the Biliary secretion. On the other hand, there can be little question that those more liquid secretions, in which there is either very little solid matter (as is the case with the Cutaneous transpiration and the Lachrymal fluid), or in which the solids, though in larger amount, are in a state of such perfect solution as to be capable of easy transudation (as is the case with the Urine), are not formed in this mode; since neither are exuviated cells normally found in the secreted fluids, nor do the epithelial cells lining the glandular tubes or follicles present indications of being in a state of continual change. Still, even in these cases, it seems fair to conclude that the *selective* powers of the gland-cells are employed in drawing from the blood, on one side, the special products which are to be set-free by transudation on the other. Each group of cells is thus adapted to separate a product of some particular kind, which

constitutes its special *pabulum;* and the rate of its production seems to depend, *cæteris paribus*, upon the amount of that pabulum supplied by the circulating fluid. The substances at the expense of which the secreting cells grow, however, may not be precisely those which are subsequently cast-forth; for it is very probable that some of them, at least, undergo a certain degree of chemical transformation by the agency of these cells; the characteristic materials of the several secretions not being always found to pre-exist *as such* in the blood.

380. A distinction may be drawn as regards this point, between those *Excretions*, the retention of whose materials in the Blood would be positively injurious, and those *Secretions*, which are destined for particular purposes within the system, and the suspension of which has no immediate influence on any other functions than those for which they are respectively destined. The solid matter dissolved in the fluids of the latter class is little else than a portion of the *nutritive* constituents of the Blood, either so little altered as still to retain its nutritive character, as is the case with the casein of Milk, and with the albuminous constituent of the Serous fluid of areolar tissue and of serous and synovial membranes; or in a state of incipient retrograde metamorphosis, as seems to be the case with the peculiar 'ferments' of the salivary, gastric, pancreatic, and intestinal secretions. On the other hand, the characteristic ingredients of the Excretions are very different in character from the normal elements of the blood. They are all of them completely unorganizable; and they possess, for the most part, a simple atomic constitution. Some of them, also, have a tendency to assume a crystalline form; which, as Dr Prout justly remarked, indicates their unfitness to enter into the composition of organized tissues. With regard to some of the chief of these, there is sufficient evidence of their existence, in small quantity, in the circulating Blood; but it is also clear, that they exist there as products of decomposition, and that they are destined to be separated from it as speedily as possible. If their separation be prevented, they accumulate, and communicate to the circulating fluid a positively deleterious character. Of this, we have already seen a striking example in the case of Asphyxia (§ 327); and the history of the other two principal excretions, the Bile and Urine, will furnish evidence to the same effect. As a general fact, then, it may be affirmed, that the materials of the proper Excretions pre-exist in the Blood, in a state nearly resembling that in which they are thrown-off by the secreting organs; and that, as their presence there is the result of the destructive changes that have taken place in the system, they cannot be retained in it without injury: but that the materials of those Secretions which are destined to perform some particular function within the economy, are derived from the nutritive substances which are appropriated to its general purposes.

381. The composition and uses of the principal Secretions which are elaborated for special purposes within the economy, have already been partly described in connection with the functions to which they respectively minister; and the remainder will hereafter come under notice in the same manner: it is here intended, however, to consider that important system of Excretory operations, which serves to maintain the purity of the circulating fluid. The process of Respiration, as already pointed-out (§ 283), is in part to be regarded as one of these; though the peculiar

manner in which it ministers to the removal of carbon and hydrogen from the system, and its subserviency to other purposes, have necessitated its separate consideration. It is obvious that the demand for the performance of these Excretory processes generally will arise, in the first place, as in the case of Respiration, from the continual disintegration and decay to which the several parts of the organized fabric are liable, in varying degrees, in the maintenance of a merely *vegetative* existence (§ 26); and this will be constant during the whole life of Man, as of any other warm-blooded animal, its amount varying with the degree of general vital activity.— But, secondly, the exercise of the *animal* functions, involving (as this does) the disintegration of the Nervous and Muscular tissues as the very condition of the evolution of their respective forces, becomes a special source of the production of excrementitious matter, the amount of which will vary with that of the forces thus developed (§ 22). The removal of excrementitious matter may become necessary, thirdly, from the *decomposition of superfluous aliment*, which has never been assimilated. This would not be the case, if the amount of food prepared by the digestive process, and taken-up by absorption into the current of the circulation, were always strictly proportional to the demand for nutriment created by the wants of the system; but such a limitation seldom exists practically, in those individuals at least who do not feel themselves obliged to put a restraint upon the indulgence of their ordinary appetite; and all that is not appropriated to the reparation of the waste, or to the increase of the bulk of the body, must be thrown-off by the excretory organs. It has been already shown, that an abundance of nutritive material in the blood does not augment the production of the principal tissues to any considerable extent (§ 353); and it would appear that all such materials as are not speedily assimilated, pass rapidly into a state of retrograde metamorphosis. How large a proportion of the solid matters of the urine ordinarily has this source, will appear from facts hereafter to be stated (§ 411).—Moreover, in the last place, it cannot be deemed improbable that the changes which the crude aliment undergoes, from the time of its first reception into the absorbents and blood vessels, to that of its conversion into organized tissues and special secretions, involve the liberation of many products, of which the elements are superfluous, and therefore injurious to the system if retained in it. Thus it has been shown* to be quite possible, that, in the production of Glutin (gelatin) from Albumen, an equivalent of Choleic (tauro-cholic) acid may be generated. The condition of Organic Chemistry, however, is not yet such as to allow of anything being advanced with certainty under this head.— From these various sources, then, a large amount of effete matter is being continually received-back from the tissues into the current of the circulation, or is generated in the blood by the changes to which it is itself subject, and it is the great object of the Excretory apparatus, to free that fluid from the products which would rapidly accumulate in it, and which would then exert a poisonous influence on the body generally, were it not for the provision which is thus made for their removal.

382. The true Secreting processes which are to be regarded as more or less completely *excretory*, are the separation of bile by the Liver, that of urine by the Kidneys, that of perspiration by the Skin, and possibly

* See Prof. Liebig's "Familiar Letters on Chemistry," p. 439.

that of fæcal matter by the glandulæ of the Intestinal surface. The sum-total of these, with the addition of the carbonic acid and watery vapour exhaled from the Lungs, and of the indigestible matter rejected in the form of fæces, must be equal to the total amount of the solid and fluid ingesta, and of the oxygen which disappears from the inspired air, the weight of the body remaining the same. Now the quantity and ultimate composition of the urine may of course be exactly determined, as may also that of the fæces: the quantity of carbonic acid thrown-off by the lungs, and of oxygen absorbed, may also be ascertained with a near approach to exactness. Hence, if we add-together, on the one hand, the solid and fluid ingesta, and the oxygen which has disappeared from the atmosphere, and deduct from this the sum of the urinary and fæcal discharges and of the carbonic acid exhaled, the difference (allowance being made for any alteration in the weight of the animal) will give the amount of aqueous fluid lost by cutaneous and pulmonary transpiration; and the proportions of the several elements of the food which pass-off by each channel, may thus be calculated with considerable accuracy.

383. Several series of observations of this kind have been recently made; some of the most important results of which will here be stated. —The following estimate, deduced by Bidder and Schmidt * from their observations upon a full-grown Cat, which was allowed for a week as much meat as it could eat, shows the mode in which the constituents of the ingesta are distributed through the excretions of *Carnivorous* animals.

Of 100 parts of		*Fæces*	*Urine*	*Pulmonary and Cutaneous Exhalation*
Water	There were given-off in	1·2 per cent.	82·9 per cent.	15·9 per cent
Carbon		1 2 ,,	9·5 ,,	89 4 ,,
Hydrogen . . .		1·1 ,,	23·2 ,,	75 6 ,,
Nitrogen . . .		0·2 ,,	99 1 ,,	0 7 ,,
Oxygen		0 2 ,,	4 1 ,,	95 7 ,,
Sulphur		50 0 ,,	50 0 ,,	—
Salts		92 9 ,,	7·1 ,,	—

In striking contrast with this, we find the distribution of the constituents of the food of *Herbivorous* animals, as deduced by Valentin from the observations of Boussingault upon a Horse,† to be as follows:—

Of 100 parts of		*Fæces*	*Urine*	*Pulmonary and Cutaneous Exhalation*
Water	There were given-off in	61·8 per cent.	5 9 per cent.	32 3 per cent
Carbon		34 6 ,,	2 7 ,,	62·7 ,,
Hydrogen . . .		40 3 ,,	2·5 ,,	57 2 ,,
Nitrogen . . .		55·7 ,,	27·1 ,,	17 2 ,,
Oxygen		41·4 ,,	1·0 ,,	57·6 ,,
Ash		85·5 ,,	16 2 ,,	-
The food generally		55·3 ,,	5·2 ,,	39·5 ,,

* See their elaborate "Verdauungssäfte und Stoffwechsel," § 289—413; also Prof. Lehmann's "Physiologischen Chemie," 2nd edit., band iii., p. 370.

† "Ann. de Chim. et de Phys.," tom. lxi., p. 128; and Lehmann, op. cit., p. 368.

The first and most remarkable feature of difference between these two sets of results, is the very large proportion which the fæcal discharges of the Horse bear to the other excretions; this obviously proceeds from the indigestibility of a large part of the alimentary substances it consumes. Of the *water* taken into the alimentary canal or formed within the body, nearly two-thirds passes-off with the fæces in the Horse, whilst nearly the whole is absorbed in the Cat; and of that which is absorbed by the Horse, little more than one-seventh passes into the urine, the remainder being exhaled from the lungs and skin; whilst in the Cat, the proportion which passes-off by the skin is less than one-sixth of that which is absorbed, the remainder being eliminated by the urine. Of the *carbon* taken into the system, a relatively-larger proportion passes-off by the lungs in the Horse, while a relatively-larger proportion enters the urine in the Cat: this is probably because the great bulk of the carbon in the food of the Horse exists in those non-azotized compounds, which can be readily converted by oxygenation into carbonic acid and water, and which consequently yield little or nothing to the urine; whilst those products of the decomposition of albuminous substances which pass into the urine, though especially rich in nitrogen, carry with them a certain measure of carbon into that excretion. It is probably for the same reason, that the amount of *hydrogen* is relatively larger in the pulmonary exhalation of the Horse, and in the urinary excretion of the Cat. On the other hand, we see that whilst the *nitrogen* of the food is almost exclusively eliminated through the urine in the Cat, as much as 40 per cent. of that which has been absorbed into the system passes-off by the lungs and skin in the Horse. Nearly the whole of the *oxygen*, in each case, passes-off by the lungs, the relatively-larger proportion in the urine of the Cat, being due to the greater amount of those products of decomposition of albuminous substances, into which oxygen enters. That half of the *sulphur* contained in the food of Carnivora, should pass off in the fæces, in an unoxidized or imperfectly-oxidized state, and that the other half should be excreted, chiefly in the condition of sulphates, formed by the oxidation of the sulphur, and by its combination with alkaline bases, is a fact of great interest, in connection with the question of the ultimate destination of the bile. For, with the exception of the small amount of sulphur contained in the undigested residue of the food, the sulphur of the fæces must be entirely derived from the bile, of which secretion it is an important constituent. But of the bile which is poured into the alimentary canal, a large part is certainly re-absorbed (§ 117), its constituents being destined to undergo oxidation, and to be eliminated, for the most part, by the respiratory process; and it is probably from this re-absorbed portion of the bile, that the sulphur of the urine is derived. It appeared from other experiments performed by Bidder and Schmidt, that, when the bile was not allowed to flow into the intestinal tube, but was collected from biliary fistulæ, from 10 to 12 per cent. of the absorbed carbon, and from 11 to 13 per cent. of the absorbed hydrogen, passes into the biliary excretion: neither the solids of the fæces, however, nor those of the urine, were sensibly affected by the abnormal removal of these constituents, which fell entirely upon the products of respiration, these being diminished to that amount. Hence it seems obvious, that although only half of the *sulphur* is taken-up again,

nearly the whole of the *hydro-carbonaceous* part of the bile must be re-absorbed, to be finally eliminated by the respiratory process; so that we may consider the entire of these constituents absorbed from the food that remains after the separation of the components of the urine, as being finally separated from the body by the respiratory process. According to Bidder and Schmidt, 100 parts of dry flesh are decomposed in the living body, with the co-operation of 167 parts of oxygen obtained from the atmosphere, into 31 parts of urinary substances, 2 parts of fæcal matter, 182 parts of carbonic acid, and 52 parts of aqueous vapour. Nearly the same relative proportions are presented when the waste of tissues is not supplied by new alimentary matter, as exist when the animal is kept on a flesh diet; so that we may regard these as representing the destination alike of the products of the ultimate metamorphosis of the tissues of the living body, and that of the products of decomposition of superfluous or unassimilated aliment of the Carnivorous animal. In the Herbivorous animal, on the other hand, only a small part of whose aliment is albuminous in its composition, the proportion just stated will apply only to that part, and to the products of the ultimate metamorphosis of its tissues; since the whole of the hydrocarbonaceous components of its food, whether saccharine or oleaginous, are eliminated by the pulmonary and cutaneous exhalation.

384. The ultimate distribution of the components of the food of Man is in most respects intermediate, as might be anticipated, between that of the purely-Carnivorous, and that of the purely Herbivorous animal. We have seen (§§ 318, 321) that, of the whole amount of *carbon* and *hydrogen* in the food, about nine-tenths are carried off by the respiratory process, the remaining tenth being divided in varying proportion between fæces and the urine. So with regard to the *nitrogen* (§ 320), for every 100 parts ingested, only 8·33 parts are ejected with the fæces, while 42·07 parts are excreted in the urine, and 49·6 parts (or nearly half) are exhaled through the skin and lungs. The following table gives the general results of the comparison of the matters assimilated and excreted, in each of the cases formerly referred-to, so that the sum in each case amounts to 100:—

	Assimilated		Excreted.			
	Food.	*Oxygen.*	*As water; by exhalation.*	*As carbonic acid.*	*Solid and fluid excretions.*	*In other ways*
A.	72·2	27·8	33·8	32 3	[illegible]	0 7
B.	75·4	24·6	36·1	28·8	34 7	0·4
C.	76·7	23·3	38·2	28·3	33 2	0 3
D.	75 3	24 7	14·5	30·2	54 6	0·7
E.	72·5	27·5	31·0	31·5	36·9	0 5

385. The experiments of Bidder and Schmidt further enable us to form some estimate of the amount of the 'change of matter,' which is required for the performance of the ordinary vital functions. This cannot be fairly measured by the amount of *excreta* given-off during a given time, whilst no fresh aliment is being introduced; since the performance of those various operations of digestion, assimilation, &c., which are necessary preliminaries to the appropriation of nutritive matter by the

tissues, itself involves no inconsiderable consumption of what was previously existing in the body. Thus it is estimated by Bidder and Schmidt, that the respective amounts of the various digestive fluids which are daily poured into the alimentary canal of an adult man weighing 14 stone, is nearly as follows.

	oz		grains	
Saliva	56·8	containing	233	of solid matter.
Bile	56·8	,,	1208	,,
Gastric juice	147·2	,,	2976	,,
Pancreatic fluid . .	7·1	,,	310	,,
Intestinal juice . .	7·1	,,	46	,,

Thus 4773 grains, or *nearly ten ounces* (troy) of solid matter, are separated from the blood in the digestive secretions, for the purpose of introducing new alimentary materials of not more than two or three times the amount; and thus we see that a large proportion of the food ingested and assimilated, must be consumed in providing for the introduction of a further supply, in addition to that which, when duly assimilated, is applied by the nutritive processes to the repair of the solid tissues. Hence we can understand the result, at first sight rather paradoxical, of the experiments of Bidder and Schmidt, which lead to the conclusion that although the loss of weight sustained by an inanitiated carnivorous quadruped is about 2·2 per cent. daily, it is by no means sufficient for the sustenance of its weight that *this* amount of food should be supplied, about *twice as much*, or 4·4 per cent., being required to keep-up its weight to the regular standard. When supplied with an unlimited amount of food, the same animal will appropriate no less than 10 or 11 per cent. of its own weight daily. The amount of oxygen daily consumed increases in like manner; being about 1·5 per cent. of its own weight in an animal taking no food, 1·8 per cent. in an animal adequately supplied, and about 4·1 per cent. in an animal highly fed (§ 316 vi.).*

386. We see, then, that whilst the *total amount* of the excretions will ordinarily depend upon the *quantity* of food ingested (the weight of the body remaining the same, and its losses of substance being duly repaired), the *relative proportion* of the different excretions will depend in great part upon the *nature* of the food consumed; the solids of the urinary excretion being especially augmented by an excess in the albuminous constituents of the food; whilst the proportion of hydro-carbon got rid-of by respiration, is very much raised by an excess of the saccharine or oleaginous. The amount voided as fæces is almost entirely dependent upon the proportion of indigestible matter in the food.—Notwithstanding, however, that, under ordinary circumstances, the several parts of the Excretory apparatus are thus limited, each to its own special function, yet we find that there are certain *complementary* relations between them, which make the action of one vicarious to a certain extent with that of another. Such a relation seems to exist, for instance, between the Lungs on one side, and the Liver and Intestinal glandulæ on the other; for, the more active the respiration, the less bile is secreted; whilst, if the respiration be lowered in amount by inactivity of body and a high external temperature, a larger proportion of unoxidized or

* Lehmann, op. cit., band iii., p. 372.

imperfectly-oxidized excrementitious matters accumulates in the blood, giving rise to that augmented production both of the biliary and of the fæcal excretions, which constitutes diarrhœa.* And thus, on the other hand, when the liver is not adequately effecting the depuration of the blood from the constituents of bile, an augmentation of the respiration by active exercise in a low temperature gives most effectual relief.—Still more obviously vicarious, however, are the Kidneys and the Skin; for here we find that not only do the kidneys allow the transudation of whatever superfluous water may remain in the circulating current, after a sufficient amount has been exhaled from the skin to keep-down the temperature of the body to its normal standard, but the skin actively assists in the elimination of one of those products of the metamorphosis of the azotized tissues, the removal of which has been until recently considered as the special function of the kidney (§ 421). Consequently, whenever the due action of the skin as an excreting organ is interfered-with, it is the kidney especially that will be called-on to take its place; whilst on the other hand, if it be thought desirable to relieve the kidney, this may be most effectually done by stimulating the skin to increased excretory activity.—This vicariousness of function among the Excretory organs presents itself far more remarkably, however, in certain states of disease, in which a complete 'metastasis of secretion' may exhibit itself. The capability of one organ thus to take upon itself the special action of another appears to be related to the 'community of function' existing in the secretory surface among those lower animals, which manifest none of the 'specialization' or setting-apart for particular offices, that we see in the higher; for it seems to be a general law in Physiology, that, even when the different functions are most highly specialized, the general structure retains, more or less, that primitive community of action which characterized it in the lowest grade of development.†

387. It is in regard to the *Urinary* excretion, that the evidence on this point is most complete; for it seems to be established by a great mass of observations, that urine, or a fluid presenting its essential characters, may pass-off by the mucous membrane of the intestinal canal, by the salivary, lachrymal, and mammary glands, by the testes, by the ears, nose, and navel, by parts of the ordinary cutaneous surface, and even by serous membranes, such as the arachnoid tunic lining the ventricles of the brain, the pleura, and the peritoneum. A considerable number of such cases was collected by Haller;‡ many more were brought together by Nysten;§ more recently Burdach has furnished a full summary of the most important phenomena of the kind;‖ and Dr. Laycock has compiled a valuable collection of cases of urinary metastasis occurring as complications of hysteria.¶ The following table of cases referred-to by the

* Such is probably the occasion of the 'bilious attacks' and 'autumnal cholera' so prevalent at the close of the summer; the subjects of these being most commonly persons who have not reduced their consumption of food during the warm season, in accordance with the diminished demand for the production of heat within the body.

† See "Princ. of Comp. Phys.," §§ 110, 428.

‡ "Elementa Physiologiæ," tom. ii. p. 370.

§ "Recherches de Physiologie et de Chimie pathologique," p. 265.

‖ "Traité de Physiologie" (Jourdan's Translation), vol. viii. p. 248, *et seq.*

¶ "Edinb. Med. and Surg. Journ.," 1838; and "Nervous Diseases of Women," p. 233.

last of these authors, will give some idea of the relative frequency of the different forms of this curious affection:—

Vomit	Stool	Ears	Eyes	Saliva	Nose	Mammæ	Navel	Skin.	Total
34	20	4	4	5	3	4	34	17	125

It is to be borne in mind, however, that cases of hysterical ischuria are frequently complicated with that strange moral perversion, which leads to the most persevering and ingenious attempts at deceit; and there can be little doubt that a good many of the instances on record, especially of urinous vomiting, are by no means veritable examples of metastasis.—The proofs of the fact we are seeking to establish are, therefore, much more satisfactory when drawn from experiments upon animals, or from pathological observations, about which, from their very nature, there can be no mistake. Thus Mayer* found that when the two kidneys were extirpated in the guinea-pig, the cavities of the peritoneum and the pleura, the ventricles of the brain, the stomach, and the intestinal canal, contained a brownish liquid having the odour of urine; that the tears exhaled the same odour; that the gall bladder contained a brownish liquid not resembling bile; and that the testes, the epididymis, the vasa deferentia, and the vesiculæ seminales, were gorged with a liquid perfectly similar to urine. Chirac and Helvetius are quoted by Haller as having tied the renal arteries in dogs, and having then remarked that a urinous fluid was passed-off from the stomach by vomiting. A remarkable case is quoted by Nysten from Zeviani, in which a young woman having received an incised wound on the external genitals, which would not heal, the urine gradually became more scanty, until none could be passed even with the assistance of the catheter; at last dropsy supervened, with sweats of a urinous odour, and vomiting of a urinous fluid, which continued daily for thirty-three years: on post-mortem examination, the kidneys were found disorganized, the right ureter entirely obliterated and the left nearly so, and the bladder contracted to the size of a pigeon's egg. In some other instances, the urine appears to have been secreted, and then re-absorbed in consequence of some obstruction to its exit through the urinary passages. Thus Nysten quotes a case from Wrisberg, in which, the urethra having been partially obstructed for ten years by an enlarged prostate, the bladder was so distended as to contain ten pounds of urine; and the serosity of the pericardium and of the ventricles of the brain exhaled a urinous odour. He cites other instances, in which the presence of calculi in the bladder prevented the due discharge of the secretion; and in which a urinous liquid was ejected from the stomach by vomiting, or was discharged by stool. A still more remarkable case is recorded, of a girl born without either anus or external genitals, who nevertheless remained in good health to the age of fifteen years, passing her urine from the nipples, and getting rid of fæcal matters by vomiting.—There are cases, moreover, in which it would seem that the mucous lining of the urinary bladder must have had a special power of secreting urine; the usual discharge having taken place to the end of life, when, as appeared by post-

* "Zeitschrift fur Physiologie," tom. ii. p. 270.

mortem examination, the kidneys were so completely disorganized that they could not have furnished it, or had been prevented by original malformation, or by ligature of the urethra, from discharging it into the bladder. A considerable number of these have been collected by Burdach.* In all the older statements of this kind, there is a deficiency of evidence that the fluids were really urinous, urea not having been obtained from them by chemical analysis, and the smell having been chiefly relied-on. The urinous odour, however, when distinct, is probably nearly as good an indication of the presence of the most characteristic constituent of human urine, as is the appearance of the urea in its separated form. The passage of a urinous fluid from the skin, has been frequently observed in cases in which the renal secretion was scanty; and the critical sweats, by which attacks of gout sometimes terminate, contain urates and phosphates in such abundance as to form a powdery deposit on the surface.

388. The metastasis of the *Biliary* secretion is familiar to every practitioner, as being the change on which *jaundice* is dependent. It is not, however, in every case of yellowish-brown discoloration of the tissues, that we are to impute such discoloration to the presence of biliary matter and we can only safely do so, when we have at the same time evidence of concurrent obstruction of the biliary apparatus. The urinary apparatus then affords the principal channel through which the biliary matter is eliminated: the urine becomes tinged with the colouring-principle of bile, being sometimes of a yellowish or orange hue, and sometimes of a brown colour with a considerable sediment; and the presence of the most characteristic constituents of the bile has been determined in the urine The same result presents itself, when the biliary duct has been artificially obstructed by ligature. Other secretions have been found tinged with the colouring matter of bile: thus the pancreatic fluid has been seen of a yellow colour in jaundice, and the milk has presented not merely the hue, but the characteristic bitterness, of the biliary secretion The cutaneous transpiration is not unfrequently so much impregnated with biliary matter, as to communicate its tinge to the linen covering the skin; and even the sputa of patients affected with bilious fevers have been observed to be similarly coloured, and have been found to contain biliary matter. The secretions of serous membranes, also, have been frequently seen to present the characteristic hue of bile; and biliary matter has been detected, by analysis, in the fluid of the pleural and peritoneal cavities. Biliary matter, however, when unduly present in the circulating current, is not removed from it by the secreting organs alone, for it seems to be withdrawn also in the ordinary operations of nutrition, entering into combination with the solid tissues. Thus, in persons affected with jaundice, we find the skin, the mucous and serous membranes, the lymphatic glands, the brain, the fibrous tissues, the cartilages, the bones and teeth, and even the hair, penetrated with the colouring matter of the bile, which they must have withdrawn from the blood, and which seems to have a particular affinity for the gelatinous tissues. It is impossible at present to say, however, to what extent the more characteristic ingredients of the bile are thus withdrawn from the blood; for the presence of

* "Zeitschrift für Physiologie," tom. ii. pp. 253, 254

its *colouring matter* cannot by any means be taken as an indication, that its peculiar *resinoid acids* are also incorporated with the normal components of the tissues.

2. *The Liver.—Secretion of Bile.*

389. The *Liver* is probably more constantly present, under some form or other, throughout the entire Animal series, than any other gland. Its form and condition vary so greatly, however, in different tribes, that, without a knowledge of its essential structure, we should be disposed to question whether any identity of character exists among the several organs which are regarded as Hepatic. It is, in fact, the presence of bile-secreting cells, that must be held to constitute a Liver; and these may be scattered over the general lining membrane of the alimentary canal, or may be restricted within follicles which are formed by depressions of it; these follicles, again, may be multiplied in some particular spot, so as to be aggregated into a mass, or may be extended into long tubes. In all the Invertebrata, however, the Liver is obviously conformable to the general type of glandular structures; the hepatic cells being in immediate relation with a basement-membrane, and being discharged upon a free surface. This will be readily understood from an examination of any one of the higher forms of it, such as that presented in the liver of the Crab, which, like the liver of the Mollusca generally, is a lobulated glandular mass, formed by the aggregation of a multitude of follicles with distinct cæcal terminations; these follicles discharging their secreted products into cavities which occupy the centre of the lobules, whence they are collected by the ducts which convey them into the alimentary canal. On a careful examination of these follicles (Fig. 55), and a comparison of the size and contents of the cells at the bottom and towards the outlet, it becomes evident that the cells originate in the former situation, and gradually increase in size as they advance towards the latter. It is also to be observed that the cells which lie deepest in the cæcum (*a*, *b*), contain for the most part the yellow granular matter, which may be regarded as the proper biliary secretion; but as they increase in size, there is also an increase in the quantity of oil-globules which they contain (*c*), until past the middle of the follicle, where they are found full of oil, so as to have the appearance of ordinary fat-cells (*d*, *e*). From this it happens, that when an entire cæcum is examined microscopically, its lower half appears filled with a finely-granular matter, intermingled with nucleated particles; and the upper half with a mass of fat-cells,

FIG. 55.

One of the Hepatic cæca of *Astacus affinis* (Cray-fish), highly magnified, showing the progress of development of the secreting cells from the blind extremity to the mouth of the follicle specimens of these, in their successive stages, are shown separately at *a*, *b*, *c*, *d*, *e*

whose nuclei are obscured by the oily particles.*—In Vertebrated animals, however, the Liver seems to be constructed upon a different plan: its component cells are no longer contained in distinct cæcal follicles or elongated tubuli branching-off from the excretory ducts, but are clustered together in masses having no immediate relation to those ducts; and there appears strong reason to consider the organ as in great part analogous to the Vascular or Ductless Glands. In ascending through the Vertebrated series, it presents a more and more solid parenchymatous texture, which strikingly contrasts with its loosely-lobulated racemose aspect in even the highest Invertebrata. This character is very obvious in the liver of Man, which is peculiarly firm and compact, and has less of connective tissue between its different parts, than is found in that of many other Mammalia.—It is observable, moreover, in the Human liver, that certain portions are rudimentary, which are elsewhere fully developed. Thus in the Carnivora and Rodentia, which present the most complex form of liver that we meet-with among Mammalia, there are five distinct parts; namely, a 'central' or principal lobe, and a right and left 'lateral' lobe, each with its 'lobular appendage.' The whole mass of the liver of Man, which we are accustomed to describe as consisting of a 'right' and 'left' lobe, does in reality form but one (there being no real division between its two portions), which must be regarded as the 'central' lobe; the 'lobulus Spigelii' is the rudiment of a right 'lateral' lobe, and the 'lobulus caudatus' is its 'lobular appendage;' but the left 'lateral' lobe, with its 'lobular appendage,' is altogether undeveloped.†

390. When the Liver is closely examined with the naked eye, it is seen to be made up of a great number of small granular bodies, about the size of millet-seeds, of an irregular form, and presenting a number of rounded projecting processes upon their surfaces. These are commonly termed *lobules*, although by some Anatomists they are spoken-of as *acini*.‡ When divided longitudinally, they have a somewhat foliated appearance (Fig. 56), arising from the distribution of the Hepatic Vein, which passes into the centre of each division. When transversely divided, the lobules are usually found to present somewhat of a pentagonal or a hexagonal shape, the angles being slightly rounded, so as to form a series of passages or interlobular spaces (B, Figs. 63–66): in these lie the branches of the Vena Portæ (as well as of the Hepatic Artery and Duct).

Fig. 56.

Connection of the *Lobules of the Liver* with the Hepatic Vein:—*a*, trunk of the vein; *b*, *b*, lobules depending from its branches, like leaves on a tree; the centre of each being occupied by a venous twig, the Intralobular Vein.

* See Dr. Leidy's 'Researches into the Comparative Structure of the Liver,' in "Amer. Journ. of Med. Sci.," Jan. 1848.

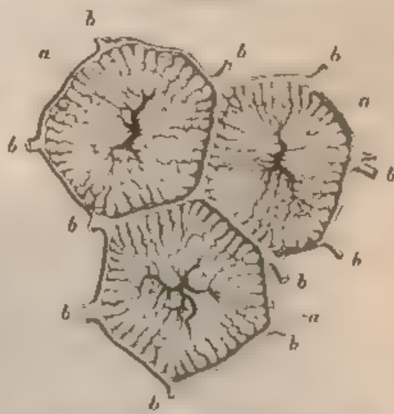
† For a general view of the Comparative Structure of the Liver in different classes of animals, see "Princ. of Comp. Phys.," §§ 405–411.

‡ The *acini* of Malpighi are the minute bodies of various forms and yellowish colour which are seen when any individual lobule is examined with the microscope; they are nothing else, however, than the irregular islets of parenchyma, left between the meshes of the plexus formed by the ultimate ramifications of the portal vein.

from which are derived the plexuses that enter the lobules. The exterior of each lobule is covered by a process of the 'capsule of Glisson,' which is very dense in the Pig and other animals, but is so thin as to be almost undistinguishable in the Human liver; its substance is composed of a parenchyma formed by a solid network of nucleated cells, the interspaces of which are occupied by the minute ramifications of the beforementioned vessels, arranged in the manner presently to be described. The structure of each lobule, then, gives us the essential characters of the whole gland.

391. The *Vena Portæ*, which is formed by the convergence of the veins that return the blood from the chylopoietic viscera, probably also receives the blood which is conveyed to the liver for the purposes of nutrition by the Hepatic Artery. Like an artery, it gradually subdivides into smaller and yet smaller branches; and at last it forms a plexus of vessels, which lie in the inter-lobular spaces, and spread with the freest inosculation throughout the entire Liver. To these vessels, the name of *inter-lobular* Veins was given by Mr. Kiernan.* They ramify in the capsules of the lobules, covering with their ramifications the whole external surface of these; and then enter their substance. When they enter the lobules, they are termed *lobular* veins; and the plexus formed by their convergence from the circumference of each lobule towards its centre (where their ultimate ramifications terminate in those of the intra-lobular or hepatic vein), is designated as the *lobular venous plexus* (Fig. 57). In the islets of this plexus (the acini of Malpighi), the ramifications of the hepatic duct are distributed, in the manner to be presently described.—The *Hepatic Artery* sends branches to every part of the Liver, supplying the walls of the portal and hepatic veins, and of the hepatic ducts, as well as Glisson's capsule. The principal distribution of its branches, however, is to the lobules; which they reach, in the same manner with the portal vessels and biliary ducts, by spreading themselves through the interlobular spaces. There they ramify upon the interlobular ducts, and upon the capsular surface of the lobules, which they then penetrate; their minuteness prevents their ultimate distribution within the lobules from being clearly demonstrable; but it is probable that they are for the most part restricted to the peripheral portions of these. As to the ultimate termination of the capillaries of the hepatic artery,—whether they

Fig. 57

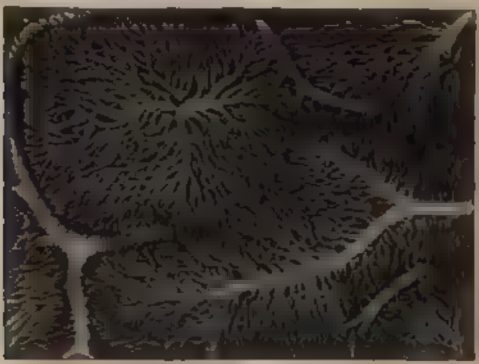


Horizontal section of three superficial Lobules, showing the two principal systems of Blood-vessels; *a, a*, intra-lobular veins, terminating in the Hepatic veins; *b, b*, inter-lobular plexus, formed by branches of the Portal vein.

* See his admirable Memoir on 'The Anatomy and Physiology of the Liver,' in the "Philosophical Transactions," 1833.

enter the Portal plexus, or the Hepatic Vein,—there is a difference of opinion amongst anatomists; the former view being upheld by Kiernan the latter by Muller. The question is a very interesting one in a physiological point of view; since, if the former account be the true one, the blood which is brought to the liver by the hepatic artery can only become subservient to the secretion of bile, by passing into the portal plexus; whilst, if the latter be the correct statement, either the arterial blood is not at all subservient to the formation of bile, or the secretion can be elaborated from the arterial capillaries. The researches of Mr. Kiernan have satisfactorily proved, that the intralobular or hepatic veins cannot be filled by injection from the hepatic artery, though they may be readily filled from the portal plexus; whilst, on the other hand, there is reason to believe, that a very fine injection into the hepatic arteries will find its way into the portal plexus.* It is certain that all the branches of the hepatic artery, of which the termination *can* be ascertained, end in the vena portæ; a free capillary communication existing between their two systems of branches, on the walls of the larger blood-vessels and ducts. According to Muller, there is an ultimate plexus of capillary vessels, with which all the three systems freely communicate; but for this idea there is no adequate foundation; and it is inconsistent with the fact just stated, that injection into the hepatic artery does not return by the hepatic vein. —It now only remains to describe the *Hepatic Veins*, the branches of which occupy the interior of the lobules, and are termed *intra*-lobular veins (Fig. 57, *a*, *a*, Fig. 58). On making a transverse section of a lobule, it

FIG. 58.



Section of a small portion of the *Liver* of a *Rabbit*, with the Hepatic or intralobular veins injected.

is seen that the central vessel is formed by the convergence of from four to six or eight minute venules, which arise from the processes upon the surface of the lobule. In the superficial lobules (by which term are designated those lobules that lie upon the exterior of the glandular

* This is stated to have been the case in the injections of Lieberkuhn, although Mr Kiernan has not succeeded in effecting it.

substance, not only upon the surface of the liver, but also against the walls of the larger vessels, ducts, &c.) the intralobular veins commence directly from their surface; and the minute venules of which each is composed, may be seen in an ordinary injection, converging from the circumference towards the centre, as in the transverse section of other lobules. The intralobular veins terminate in the larger trunks, which pass along the bases of the lobules, collecting from them their venous blood; these are called by Mr. Kiernan *sub-lobular* veins. The main trunk of the Hepatic Vein terminates in the ascending Vena Cava.

392. The *Hepatic Duct* forms, by its subdivision and ramification, an interlobular plexus very like that of the portal vein; but the anastomosis between the branches going to the different lobules is less intimate than that of the interlobular veins, and cannot be directly demonstrated; although Mr. Kiernan thinks that his experiments leave but little doubt of its existence,—a communication (which cannot be seen to be established by any nearer channel) being proved to exist between the right and left primary subdivisions of the duct. The interlobular ducts ramify upon the capsular surface of the lobules, with the branches of the portal vein and hepatic artery; but they cannot be traced into their interior; and most recent observers agree in affirming that they do not enter their parenchymatous substance. To use the language of Prof. Kolliker,* "Whatever view we may take of the connection of the hepatic cell-network with the efferent biliary canals, it is undeniable that any such connection only takes place *upon the surface of the hepatic islets* (lobules), and not in their interior; and that, therefore, the bile which is formed there *must be transmitted outwards from cell to cell*," in the manner in which fluids are transmitted through closed cells in plants. The probable relation of these two components of the Hepatic structure, is shown (diagrammatically) in Fig. 59.—The terminal portions of the biliary ducts† are crowded with nuclear particles and granular matter, resembling that which forms the intercellular plasma of the lobules; there are also cells which seem to be identical with those of the parenchyma, except that their walls are thinner and their contents more pellucid; and fragments of similar cells are often to be seen; whilst the columnar epithelium which lines the larger ducts, is almost or

Fig. 59.

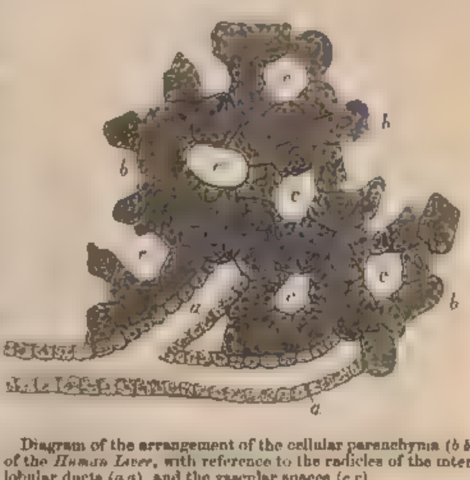


Diagram of the arrangement of the cellular parenchyma (*b b*) of the *Human Liver*, with reference to the radicles of the interlobular ducts (*a a*), and the vascular spaces (*c c*)

* "Manual of Human Histology," (Sydenham Society's Edit.), vol. ii., p. 119.
† See Mr. Wharton Jones, in "Philos. Transact.," 1848, p. 277.

entirely wanting. These appearances may be considered to indicate that an active secretory function is going-on in this situation.

393. The substance of each lobule may be considered as a *solid network*

Fig. 60.*

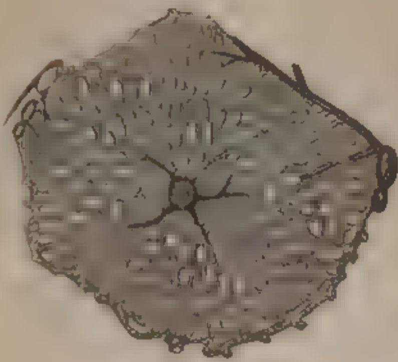


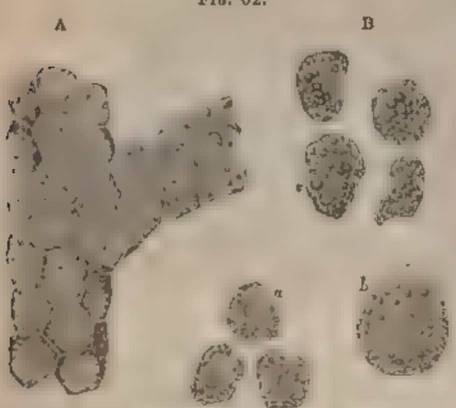
Fig. 61.†

* Transverse section of a *Lobule* of the Human Liver, showing the reticular arrangement of its parenchyma, with some of the branches of the Hepatic Vein in the centre, and those of the Portal Vein at the periphery.

† A small portion of this section more highly magnified, showing the columns of secreting cells of which the parenchyma is composed.

of parenchyma (Figs. 60, 61), composed of cells; the interspaces of which are so completely occupied by the vascular network already described, that, when the latter is fully injected, no vacuities are seen. The meshes of the parenchymatous network have a more rounded form towards the margin of the lobule, whilst in the centre they are disposed more radially; so that in a section cutting the intralobular vein transversely long branching columns of hepatic cells are seen stretching from the latter on all sides, and uniting by short lateral anastomoses (as in Fig. 61), so that the intermediate meshes appear like narrow elongated clefts. These columns (Fig. 62, A) usually consist of from three to five rows of cells, and are generally cylindrical or prismatic, but not at all regularly

Fig. 62.



A, portion of a *Hepatic Column*, from Human Liver, showing the component secreting cells; B, secreting cells detached, a, in their normal state; b, a cell more highly magnified, showing the nucleus and distinct oil particles; c, in various stages of fatty degeneration.

so. Fragments of them are almost always to be found among scraped-off particles of the liver.*

394. The *biliary cells* of the Human liver (Fig. 62, B) are usually of a flattened spheroidal form, and from 1-1500th to 1-2000th of an inch in diameter. Each of them presents a distinct nucleus; and the cavity of the cell is occupied by yellow amorphous biliary matter, usually having one or two large adipose globules, or five or six small ones, intermingled with it (*a*, *b*). The size and number of these, however, vary considerably, according to the nature of the food, the amount of exercise recently taken, and other circumstances. If an animal be very fat or be well fed, especially with farinaceous or oleaginous substances, the proportion of adipose particles (*c*) is much greater than in an animal moderately fed and taking much exercise. The size of the oil-globules varies from that of mere points, scarcely distinguishable from the granular contents of the cells except by their intense blackness, up to one-fourth of the diameter of the cell. A still greater accumulation of adipose particles in the biliary cells, gives rise, as was first pointed out by Mr. Bowman,† to the peculiar condition termed 'fatty liver' (§ 397). The finely-granular matter is the portion from which the colour of the cell is derived; it seems to fill the space not occupied by the oil-globules, and it often obscures the nucleus, so that the latter cannot be distinguished until acetic acid is added, which makes the granular matter more transparent without affecting the nucleus.—The cells are imbedded in a diffused granular plasma, in which young cells are observable; these being apparently formed by a collection of free nuclei. It has been usually supposed that the hepatic cells ordinarily contain *biliary* matter; but such, from the recent enquiries of Dr. C. Handfield Jones,‡ appears not to be the case, save in exceptional instances, though the *colouring* matter which they contain seems to be identical with that of the bile. But the peculiar *sugar* which is found in the blood of the hepatic vein (§ 185), is nearly always detectable throughout the cellular parenchyma; being least abundant, however, when the cells are loaded with fat, which is more commonly the case with those of the periphery than with those of the centre, of the lobules.

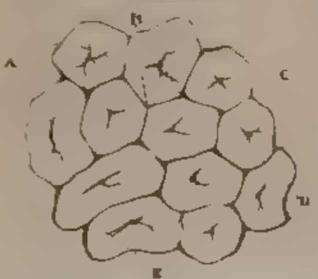
395. Before proceeding to consider the physiological actions of this organ, we may stop to notice some of those Pathological changes occasionally seen in it, which have a most intimate relation to the structural details already given. The first class of alterations in its appearance to which we shall refer, is connected with abnormal conditions of its Circu-

* This plexiform arrangement of the cellular parenchyma of the Liver, has led several eminent Anatomists (among them Prof. Retzius, Dr. Leidy, and Dr. Guillot) to the belief that the *biliary ducts* form a plexus through the interior of the lobules, and that the hepatic cells line their interior. Although he had never been able to confirm the statements of these observers respecting the existence of a basement membrane around the 'columns' of hepatic cells, yet he was so far satisfied of the correctness of their statements on other points, as to have accepted this one, in former editions, without questioning its correctness. Further enquiry, however, has satisfied him that the view of the compound nature of the Hepatic structure, which Dr. C. Handfield Jones was the first to propound ("Philosophical Transactions," 1846, 1849, and 1853), and which harmonises with Prof. Kölliker's account of its structure (op. cit.), is really the correct one, this view, moreover, being strikingly confirmed and illustrated by the parallel order of anatomical and physiological facts presented by the Vascular Glands.

† 'Medical Gazette,' Jan. 1842. ‡ "Philosophical Transactions," 1853.

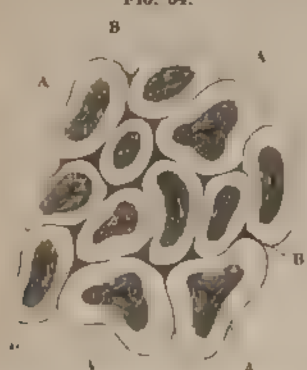
lation, as was long-since discovered by Mr. Kiernan (loc. cit.). When the liver is in a state of *Anæmia* (which rarely happens as a natural condition, although it may be induced by bleeding an animal to death), the whole substance of the lobules is pale, as represented in Fig. 63. In general, however, the liver is more or less congested at the moment of death; and this congestion may manifest itself in several ways. The whole substance may be congested; in which case the lobules present a nearly-uniform dark colour throughout their substance, their centres being usually more deeply-coloured than the margins. An appearance more frequently offered after death, however is that represented at Fig 64, and termed by Mr. Kiernan the *first stage* of *Hepatic Venous* congestion. In this, the isolated centres of the lobules alone present the colour of sanguineous congestion; and the surrounding substance varies from a yellowish white, yellow, or greenish colour according to the quantity and quality of the bile which it contains. The accumulation of the blood in the hepatic veins, and the emptiness of the portal plexus, seem due to the continuance of capillary action after the general circulation has ceased; a circumstance to which we find an exact parallel, in the emptiness of the systemic arteries, and the fulness of the veins, after most kinds of death (§ 269).—In the *second* stage of Hepatic Venous congestion, the accumulation of blood is found not only in the intralobular veins, but even in parts of the portal or lobular venous plexus. The parts which are freest from it, are those surrounding the interlobular spaces; so that the non-congested substance here appears in the form of circular or irregular patches, in the midst of which the spaces and fissures are seen (Fig 65).* Although the portal as well as the hepatic venous system is thus involved in this form of congestion, yet, as the obstruction evidently originates in the latter, the term given by Mr. Kiernan is still applicable; and it is important to distinguish this

Fig. 63.



A, angular lobules in a state of *Anæmia*, as they appear on the external surface of the liver. B, interlobular spaces, C, interlobular fissures, D, interlobular veins, occupying the centres of the lobules, E, smaller veins, terminating in the central veins.

Fig. 64.

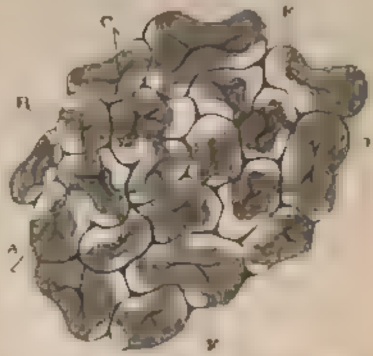


A, rounded lobules in *first* stage of *Hepatic Venous congestion*, as they appear on the surface of the liver, B, interlobular spaces and fissures.

* This very common aspect of the Liver, which presents numerous modifications, has been a source of great perplexity to those who have studied the minute anatomy of the organ, and has even led Anatomists of the highest eminence into serious errors. See Mr Erasmus Wilson, in "Cyclop. of Anat. and Physiol.," vol. iii. pp. 185, 186

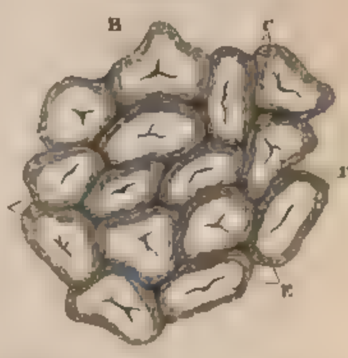
appearance from that next to be described. The second stage of Hepatic Venous congestion very commonly attends disease of the heart, and other disorders in which there is an impediment to the venous circulation; and in combination with accumulation in the biliary ducts, it gives rise to some of those appearances which are known under the name of dram-drinkers' or nutmeg liver.—The other form of partial congestion arises from an accumulation of blood in the portal veins, with a reverse condition of the hepatic or intralobular veins; in this condition, which Mr. K. designates as *Portal Venous congestion*, the marginal portions of the lobules are of deeper colour than usual, and form a continuous network, the isolated spaces between which are occupied by the non-congested portions (Fig. 66). This is a very rare occurrence; having been seen by Mr. K. in children only.—These differences fully explain the diversity in the statements of the older anatomists, as to the relative position of the so-called *red* and *yellow* substances; for it now appears, that the *red* substance is the *congested* portion of the lobules, which may be either interior, or exterior, or irregularly-disposed; whilst the *yellow* is the *non-congested* part, in which the biliary plexus shows itself more or less distinctly.

FIG. 65.



A, lobules in the *second stage* of *Hepatic Venous congestion*. B, and C, intralobular spaces; D, congested intralobular veins; E, congested patches, extending to the circumference of the lobules; F, non-congested portions of lobules.

FIG. 66.



A, lobules as they appear on the surface in a state of *Portal Venous congestion*. B, interlobular spaces and fissures; C, intralobular hepatic veins, containing no blood; D, the central portions in a state of anæmia; E, the marginal portions in a congested state.

396. Another very interesting form of Pathological change in the aspect of the Liver, which the knowledge of the structure of the lobules enables us to comprehend, is that 'granular-degeneration' which is very apt to supervene upon Inflammatory affections of the organ, and of which one form has been known as *Cirrhosis*. The liver thus affected* is usually diminished in bulk, sometimes considerably so; it is harder and denser than usual; and its surface is roughened by the projection of a vast number of minute bodies, varying in size from that of a pin's head to that of a

* The resemblance which the cirrhosed Liver often bears to the sole of a shoe beset with hob-nails, has occasioned it to be designated 'hob-nailed liver,' whilst, from the cause to which the various forms of granular degeneration are most frequently traceable, the organ thus affected is often described as 'gin-liver.'

hazel-nut, whilst the connecting tissue shrinks-in. The whole substance of the viscus is altered in the same manner. When the bodies are minute and closely set, they impart what appears at first to be a uniform brownish yellow tint to the divided surface; but, when more carefully examined, their separation becomes evident, their own hue being a deep yellow, like unbleached wax,—an appearance which makes it not surprising that Laennec should have been led to regard them as formed by a new deposit, analogous to that of tubercular matter. It was first suggested by Cruveilhier, that the yellow bodies really consist of the proper substance of the liver; and that they are formed by the excessive development of a portion of the lobules, consequent upon atrophy of the remainder. This, however, is not exactly the case; for, whether minute granules or larger bodies, they are small uncongested patches, composed of parts of several adjoining lobules, and having one or more interlobular spaces for a centre; their yellow colour being simply that of the parenchyma in excess charged with bile, or, at least, with its colouring matter. The intervening portions of the hepatic substance are more or less completely atrophied; and the proper parenchyma is partly replaced by adventitious fibrous tissue, which interpenetrates the whole mass of the organ, thus imparting to it greater solidity than usual.—The mode in which this change is induced, has been carefully studied by Dr. G. Budd,* who has shown that it begins in inflammatory action, either acute or chronic. The former is rare in this country; but a form of the latter, termed by Dr G. Budd 'adhesive inflammation of the liver,' is comparatively frequent, especially among spirit-drinkers. This disease seems distinctly traceable to the irritation produced in the organ, and especially in the lining membrane of its blood-vessels, by the presence of alcohol taken into the circulating current through the radicles of the portal vein; and it results in the partial or complete obliteration of some of the branches of that trunk which carry its blood through the liver, and also in the effusion of plastic lymph in the interlobular spaces throughout the substance of the viscus, which gradually consolidates into a fibrous tissue, that forms thin bands between small irregular masses of the lobules, and undergoes a gradual contraction. Both these causes will operate to produce atrophy of a considerable part of the parenchyma of the liver, and a drawing in of the capsule at the parts corresponding to those lines of fibrous tissue; whilst the islets that still receive their due supply of nutriment, become hypertrophied, and project from its surface.

397. Among the most frequent of the pathological changes which the assistance of the Microscope enables us to discern in the *hepatic cells*, is that engorgement with adipose particles, which is observable in the condition of the organ known as 'fatty liver' (Fig 67). This state having been frequently observed in individuals who have died of phthisis or other diseases of the lungs involving deficient respiration, has been imputed to a vicarious action of the liver, which (as it was supposed) made an effort thus to discharge the hydro-carbonaceous matters that should normally be eliminated by

Fig. 67.

Hepatic Cells gorged with *Fat*: *a*, are placed nucleus; *b*, adipose globules

* See his "Treatise on Diseases of the Liver," 2nd Edit

the lungs. But such a view is inconsistent with various facts, which show (as Mr. Paget has justly remarked)* that the fatty liver is an inactive organ, one which is discharging *less* than its ordinary function, and that the accumulation of fat in its cells is rather to be considered as a mark of 'fatty degeneration.' For the nuclei disappear, the proper colouring-matter of the bile can no longer be distinguished, the liver increases in size owing to the tardy or obstructed removal of its cells, and its paleness indicates a slow and defective supply of blood; moreover the fatty liver presents itself in many cases in which there has been no deficiency of respiration, and is frequently absent in phthisical subjects; and there is no evidence whatever, that the organ when in this state discharges any unusual amount of fat into the alimentary canal. Still there can be little doubt, that the accumulation of adipose matter in the biliary cells is favoured by deficiency of respiration; for a marked relation of reciprocity is discernible throughout the Animal series, between the amount of fat contained in the Hepatic apparatus, and the activity of the Respiratory function, thus in Birds, the biliary cells scarcely contain any fatty particles, whilst in Reptiles and Fishes they are loaded with them; and nearly the same difference may be seen between the biliary cells of Insects, and those of Crustacea and Mollusca. This difference, however, is probably due to the circumstance, that the fat which it is one office of the Liver to form (§ 185), is at once carried away by the venous blood, to be eliminated by the lungs, in animals whose respiration is active; whilst it remains stored up in the parenchyma of the organ, in those whose respiration is comparatively feeble.—Various other alterations, however, have been noticed. Dr. T. Williams mentions,† that, in a case of obstruction of the ductus choledochus by malignant disease, which occasioned complete interruption to the passage of bile, and consequent jaundice, scarcely an entire nucleated cell could be discovered by attentive examination of a large part of the organ. Nothing more than minute free particles of fat, and free floating amorphous granular matter, could be detected. He further states that, in a case of fever, the hepatic cells were found to be almost entirely destitute of fatty particles, and that in 'granular liver,' the cells of which the granules consist, strongly resemble the ordinary cells of the parenchyma of the liver in every respect, except that they are almost or completely destitute of yellow contents. Similar observations have been also recorded by Dr. G. Budd.‡—In two cases of jaundice examined by Mr. Gulliver, the hepatic cells were gorged with biliary matter, some of them to such an extent that they had become nearly opaque: perhaps if this condition had continued, these cells would have been all ruptured, and the state of the organ would have resembled that described by Dr. Williams.

398. When we take a general survey of the structure of the Liver in Man and the higher Vertebrata, and of the relation of its parenchymatous tissue to the blood vessels on the one hand and to the excretory ducts on the other,—and when we compare these arrangements with those that exist in the Vascular Glands and in the ordinary Secreting Glands,—we find strong reason to regard the organ as sharing in the structural

* 'Lectures on Nutrition,' &c. in "Medical Gazette," 1847, vol. xl., p. 235.
† "Guy's Hospital Reports," 1843.
‡ See his Treatise on "Diseases of the Liver," 2nd edit., pp. 211, 247, &c.

characters of both those classes of bodies, and as likely to perform the double function of Assimilation and Secretion. And this inference harmonizes well with all the facts which have been ascertained with regard to its operation on the blood. For, as we have already seen (§ 132), there is very clear evidence, that the Blood in circulating through the liver is so changed in its character, as to be rendered more fit to support the body; and this, not only by the removal of matters whose presence would be noxious, but also by a conversion or higher elaboration of those which are destined for the purposes of nutrition. Now this is probably the special purpose of the parenchymatous tissue, which is traversed by the blood in its passage from the Portal to the Hepatic Veins, just as the parenchyma of the Peyerian and Absorbent Glandulæ, of the Malpighian bodies, of the Spleen, &c., is traversed by blood distributed through their capillary plexuses by the Systemic Arteries. On the other hand, the biliary ducts with their contained cells, which are supplied by the Hepatic Artery, probably constitute (as elsewhere) the proper secreting apparatus.—This view of the double character and function of the Liver in Vertebrated animals, harmonizes well, as will be shown hereafter (Chap. XVI., Sect. 4), with the history of its development, for it exists, in the first place, as a parenchymatous mass, which originates independently of any offset from the Alimentary Canal, and essentially resembles those masses of which the assimilating glands are composed; a diverticulum of the intestine extends itself towards this, and gradually pushes its ramifications into its substance; but these (as we have seen) never proceed further than the exterior of each of those little collections of parenchyma that forms a lobule.*—Although, however, we may regard the *converting* and the *secreting* actions as the special attributes of two different portions of the apparatus, there does not appear to be adequate reason for supposing that they are entirely disconnected, and that the parenchymatous substance of the liver takes *no* part in the secretion of bile. On the contrary, there seems every probability, from the intimate association of the two sets of actions in the same organ, that the one is to a certain extent the *complement* of the other; biliary matters being eliminated in the very act of that metamorphosis, to which certain components of the blood are subjected. The ordinary absence of the peculiar biliary compounds from the contents of the hepatic cells,† is no objection to this view; since, if this matter be transmitted from cell to cell, towards the periphery of the lobule, as fast as it is formed, we should no more expect to find it in the parenchyma, than we expect to find any quantity of urea in the blood when the kidneys are duly performing their function. On the other hand, that the cells of the hepatic parenchyma are occasionally found to be turgid with biliary matter, when the final eliminating process is in some way interfered with, seems to indicate that they are concerned in its separation from the blood; although this action may be altogether subordinate to the converting influence which they exercise upon the blood itself.

399. Bile is a viscid, somewhat oily-looking liquid, of a greenish-yellow colour, and very bitter taste, followed by a sweetish after taste. It is readily miscible with water, and its solution froths like one of soap

* See Huxley in "Quart. Journ. of Microsc. Science," vol. ii. p. 82.

† See the evidence of this, adduced by Dr. C. Handfield Jones, in "Phil. Trans.," 1853.

The proportion of solid matter which it contains, is usually from 9 to 12 per cent., and nearly the whole of this consists of substances peculiar to Bile.—The following are the general results of the analyses made by Berzelius, of Human Bile, and of that of the Ox:—

	MAN	OX
Water	90·44	92·84
Biliary matter	8·00	5·00
Mucus of the gall-bladder	·30	·23
Soda	·41	
Chloride of sodium, and extractive	·74	1·50
Phosphates and sulphates of soda and lime	·11	·43
	100·00	100·00

In the Biliary matter, according to the researches of Strecker (which are undoubtedly the most accurate and satisfactory that have been hitherto made), the following substances may be distinguished:—Two resinous acids, the *Glycocholic* (which is the *cholic* of Strecker and many former authors) and the *Taurocholic* (which is the *choleic* acid of Strecker, and is nearly the same with the bilin of other chemists); these are formed, according to Lehmann, by the 'conjugation' of Cholic acid with glycine (gelatine-sugar) and taurine respectively; and they are united in the bile with soda as a base. It is in the tauro-cholic acid that the sulphur of the bile presents itself, no less than 25 per cent. of that element existing in taurine, so that the proportion which this acid bears to the glycocholic (which differs greatly in different animals) may be estimated by the amount of sulphur in the mixture of the two. Besides a variable quantity of the ordinary Fatty acids, Bile also contains *Cholesterin*, a non-saponifiable crystalline fatty substance; and also a peculiar *pigment* (very rich in carbon, and apparently related to the colouring-matter of the blood), which forms, in combination with lime, the insoluble granular matter that may be distinguished in bile by microscopic examination.—It is remarkable that, notwithstanding the comparatively-minute proportion in which these two last substances exist in ordinary bile, cholesterin should usually be the principal ingredient of the biliary concretions which are frequently found in the gall-bladder and bile-ducts; and that the bile-pigment with its calcareous base should also occasionally accumulate, so as to form solid masses which consist of little else. It would appear from this, that the peculiar resinous acids of the bile are far more readily re-absorbed, than are its other ingredients; and this corresponds with the results of experiments upon the contents of the alimentary canal, which show that whilst the colour of the fæces is chiefly due to the presence of bile-pigment, the conjugated acids are scarcely to be recognized in them.

400. The quantity of Bile ordinarily secreted by the liver, the circumstances which favour or retard its production, the mode in which it is discharged into the intestine, and the purposes which it answers in the Digestive process, having all been considered under a previous head (§§ 110–112), we have now to enquire into the conditions under which the Secretion takes place; and one of the most important of these, is the supply of Blood which the Liver receives. How far the blood supplied by the Hepatic Artery is the immediate source of the secretion, cannot be positively ascertained; there is no doubt, however, that it may

become so indirectly, by finding its way into the portal system. For, if the Vena Portæ be tied, the secretion of bile still continues, though in diminished quantity; and several cases are on record, in which, through a malformation, the vena portæ terminated in the vena cava without ramifying through the liver, and in which secretion of bile took place,—evidently from the blood of the hepatic artery, which appeared to have passed into the ramifications of the umbilical vein, these forming a plexus in the lobules, that exactly resembled the ordinary portal plexus.*—What effect the interruption of the supply of blood by the Hepatic Artery would have upon the amount of bile, has not yet been experimentally determined; but as its area is not more than one-eighth that of the Portal vein, and as the great diminution of the secretion when the latter is tied shows that *its* blood furnishes the chief part of the materials of the fluid, it may be fairly considered that the supply of blood by the Hepatic Artery is by no means essential to the act of secretion, although it may well be to the nutrition of the organ. The case of the Lungs, which are supplied with arterial blood by the bronchial vessels, as well as with venous blood by the proper pulmonary trunks, seems on the whole analogous; the chief point of difference being, that the bronchial arteries have corresponding veins of their own, instead of discharging their blood into the pulmonary current.—The fact that the secretion of Bile is thus normally formed, in great part at least, from *venous* blood, has been commonly connected with the hydrocarbonaceous nature of its chief components, which must exist (it is considered) in larger proportion in such blood than in that of the arteries. But it must be borne in mind, that the urinary excretion, which is undoubtedly formed at the expense of the products of the disintegration of the tissues, is secreted from arterial blood; and since the bile is, as it were, the *complement* of the urine (the ultimate components of the two together making-up the composition of blood†), there seems no reason why arterial blood should not furnish its materials, as abundantly (or nearly so) as venous. The real explanation of the peculiar relation of the Liver to the Venous circulation, is probably to be found in the action of the organ upon the matters newly absorbed into the circulation from the alimentary canal. That this action is not

* Such, at least, was found to be the case, in the only instance in which the Liver was examined with sufficient care. See Kiernan, loc. cit.

† It has been pointed-out by Prof. Liebig, that if we add to half the formula representing the ultimate composition of *bile*, the formula of *urate of ammonia* (which is the characteristic component of the urine of all animals save Mammalia), the sum gives the proportionals of the ultimate components of dried *blood* or of *flesh*, with the addition of 1 equiv. of oxygen and 1 equiv. of water. For

½ Equiv. of Biliary matter = 38C, 33H, N, 11O
1 Equiv. of Urate of Ammonia = 10C, 7H, 5N, 6O

The Sum of which = 48C, 40H, 6N, 17O

And in like manner

Formula of Blood = 48C, 39H, 6N, 15O
1 Equiv. of Water + 1 Equiv. of Oxygen = H, 2O

48C, 40H, 6N, 17O

Although these formulæ can by no means be supposed to represent the process which actually takes place, yet the coincidence is so close, as to indicate that the complementary relation spoken-of above has a real existence.

only assimilative, as already shown (§ 132), but is also to a certain extent depurative, appears from the fact that the liver tends to remove from the blood, and to store-up in its own substance, certain foreign matters of an injurious kind,—such as copper and arsenic,—which have found their way into the tributaries of the portal system. This seems also to be the case with respect to pus, which, when taken-up from ulcers in the intestinal walls, is stopped in the liver, and not unfrequently gives rise to abscesses in its substance.*

401. How far the constituents of the Bile are *preformed in the Blood*, or to what extent they are *elaborated by the Liver*, is not yet certainly determined. It might be expected, that if, like the components of the urinary secretion, they pre-exist in the circulating current, and are merely eliminated from it by the agency of the Liver, they would accumulate in it when that elimination is checked by the removal of the secreting organ; yet Muller, Kunde, Lehmann, and Moleschott have carefully examined the blood of frogs thus treated, without finding any traces either of the peculiar resinous acids, or of the colouring matters of bile.†—Even though the materials of the biliary secretion, however, should receive their complete and characteristic form in the liver itself, it is not less certain that they are produced at the expense of substances of an excrementitious character, whose retention in the circulating current would be injurious; this being strikingly demonstrated by the disturbance of the functions generally, and especially of those of the Nervous system, which is consequent upon the suspension of the secreting process. When the suppression is complete, the powers of that system are speedily lowered (almost as by a narcotic poison), the patient suddenly becomes jaundiced, and death rapidly supervenes.‡ When the secretion is diminished, but not suspended, the same symptoms present themselves in a less aggravated form. It is probable that much of the disorder in the functions of the brain, which so constantly accompanies deranged action of the digestive system, is due to the less severe operation of the same cause, namely, the partial retention within the blood, of certain constituents of the bile, which should have been eliminated from the circulating fluid. Such an abnormal accumulation, which may depend either on a deficiency in the functional activity of the liver, or on an excess of the excrementitious matters brought to it for elimination, is habitual

* See Dr. G. Budd's "Treatise on Diseases of the Liver," 2nd edit., Chap. ii., sect. 1.

† See the second edition of Prof. Lehmann's "Physiologischen Chemie," band ii. pp. 75, 76.—It has been already stated, however, that Enderlin affirms cholic acid to be a normal ingredient of the blood (§ 172 *note*), so that the matter must be regarded as still undetermined.

‡ See Prof. Alison in "Edinb. Med. and Surg. Journ.," vol. xliv., and Dr. Budd, Op. Cit., Chap. iii.—From the evidence collected by Dr. Budd, he is led to think it probable that the cerebral symptoms are not due to the simple retention of the materials of Bile, but depend upon some metamorphosis which these undergo whilst circulating with the blood, whereby a more toxic poison is generated. For the general symptoms of suppression of the secretion may have shown themselves for some time, before any serious disturbance occurs in the cerebral functions, and this may supervene very suddenly, and be fatal in a few hours (p. 263). The analogy of Uræmia (§ 400) seems to afford some confirmation to this view; but it must be borne in mind as a possible explanation of the phenomena, and one which has evidence in its favour, that the kidneys, by a vicarious action, remove the most poisonous of the retained biliary matters, and that it is only when *they* can no longer effect this, that the results of the accumulation of these matters begin to show themselves in the perversion of the functions of the nervous centres.

in some persons; and it produces a degree of indisposition to bodily or mental exertion, which it is difficult to counteract. More, probably, is to be gained in such cases by the regulation of the diet, especially the reduction of its hydro-carbonaceous components, and by active exercise (which, by augmenting the respiration, will promote the elimination of any superfluity of this kind through the lungs), than by continually inciting the liver to increased functional activity, by medicines which have a special power of temporarily augmenting its energy.—The excrementitious character of the Biliary secretion is very strikingly indicated by its formation during fœtal life;* which, as it can then have reference neither to the function of Digestion nor to that of Respiration, must be regarded as having for its purpose to free the blood of matter which would be injurious to it. And this matter can hardly arise from any other source, than the 'waste' of the tissues (consequent upon the limited duration of their existence), which takes place even when the life of the organism is most purely vegetative. The *re-absorption* of Bile into the blood, as seen in ordinary cases of jaundice dependent upon the obstruction of the biliary ducts, does not act on the general system in a manner nearly so injurious, as the *retention* of the matters at the expense of which it is formed has been shown to do;† in fact, much of the disturbance which then ensues, may be attributed to the disorder of the digestive function which is consequent upon the stoppage of the flow of bile into the intestinal canal (§§ 111, 112). And when it is further remembered, that the greater part of the bile which passes into the intestinal canal is ordinarily destined for re-absorption (§ 117), it seems fair to conclude that the matters which accumulate in the blood when the secreting action of the liver is suspended, are not in the same condition with those which are received-back into it after being submitted to that action and that the liver, therefore, not merely separates them, but exercises a certain *transforming* agency upon them.

402. From what components of the Blood the materials of the biliary secretion are immediately derived, is a question that cannot yet be answered with more certainty than the preceding. The close resemblance in composition, between the resinous acids of bile, and the ordinary fats (especially olein), naturally suggests the idea that they are drawn from the fatty matters of the blood; but to this notion there are many serious objections, both physiological and chemical. One of the most important of these is the fact ascertained by MM. Bidder and Schmidt, that the flow of bile is not increased by a predominance of fat in the food, and that animals fed exclusively on fat do not secrete more bile than those entirely deprived of food: whilst it has been found by

* It has been shown by Simon and Frerichs, that the *meconium* which is contained in the intestinal canal at birth, is chiefly composed of accumulated bile.

† Dr. Budd mentions several cases (Op. cit. pp. 205–227), in which the passage of bile into the intestines was entirely prevented by the complete closure of the ductus communis and in which, nevertheless, life was prolonged for many months; in one of these the jaundice first occurred in a woman four months pregnant, who nevertheless bore a healthy child at the full period, and suckled it up to the time of her death, which happened when the child was three months old. In all these cases, death seemed to result from gradual exhaustion, consequent upon the imperfect assimilation of food, rather than from any toxic agency; and this even when the liver was in such a state of disorganization, that its functional activity must have been suspended for some time before death.

Nasse, that the presence of a large amount of protein-compounds in the food occasions a great augmentation in this secretion.* The increase of the secretion after each ordinary ingestion of food (§ 112), and its marked and progressive diminution in animals entirely deprived of aliment (as determined by MM. Bidder and Schmidt), seem to indicate that its materials may be directly derived in part from proteinaceous materials which do not undergo metamorphosis into tissue; whilst on the other hand, there is every reason to believe, that the production of the components of bile is a necessary part of those processes of retrograde metamorphosis, by which the materials of the effete tissues are removed from the system.—But it is not the formation of *bile* alone, that is effected by the Liver at the expense of these substances; for the experiments of M. Cl. Bernard† have clearly proved, that the peculiar *sugar* which is found in the blood of the hepatic vein, and which may be extracted also from the substance of the liver itself, may be generated at the expense of protein-compounds; and the same is probably the case with the liver-*fat*, the production of which seems to be in great degree vicarious with that of sugar. Now these substances are not less truly products of *secretion*, than is the bile itself; although they are carried off by the blood of the hepatic vein, and are directly eliminated by the lungs, instead of being withdrawn from the current of the circulation, and discharged through the biliary ducts into the alimentary canal.—Taking all these considerations into account, we seem entitled to conclude, that besides its operation as an Assimilating organ, whereby it helps to prepare histogenetic materials for conversion into blood and solid tissue, the Liver exerts its Secretive action, in separating the hydrocarbonaceous portion of the protein-compounds which are destined to undergo retrograde metamorphosis, as being either *superfluous* or *effete*; and this under the three forms of Sugar, Fat, and Bile. The two former, if not at once removed by the blood-current, remain stored-up in the liver itself, as a pabulum for respiration; the latter, being of use in the digestive operation, is first poured into the alimentary canal, from which, however, the greater part is subsequently reabsorbed, its components being oxidated and then eliminated through other channels, the Hydro-Carbon as water and carbonic acid through the Lungs, the Sulphur as sulphuric acid through the Kidneys.

403. Not only in thus helping to decompose the protein-compounds, and to eliminate from them the appropriate materials for the combustive process (so that the immediate *pabulum* of that process is the same in Carnivorous, as in Herbivorous animals), is the Liver subservient to the Respiratory function. For it converts all forms of *saccharine* matter derived from the food into 'liver-sugar,' the form which is most favourable to oxidation; and it exercises a similar transforming power upon *fatty* matter, generating the peculiar 'liver fat,' from other oleaginous or from saccharine substances supplied by the food. It is not, then, so much by the separation of bile (as formerly propounded by Prof. Liebig), as by the change which it effects in the circulating blood, that the Liver prepares the materials adapted for the sustenance of the combustive operation. For it is quite certain, that if the whole of the solid

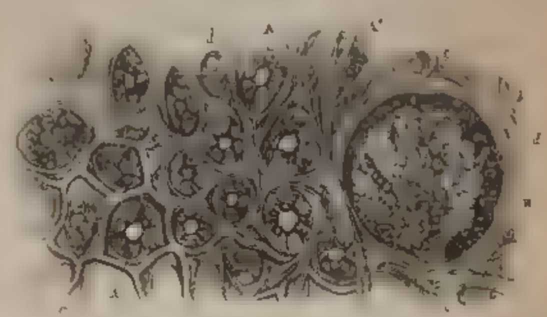
* See Prof. Lehmann's "Physiologischen Chemie," 2nd edit., band ii., pp. 64-66.
† "Nouvelle Fonction du Foie," (1853), chap. ii.

biliary matter poured into the intestine were re-absorbed, it could furnish but a small proportion (probably not more than one twelfth) of the total amount of hydrocarbon which is eliminated by the lungs; and the preparation of the liver-sugar and liver-fat in the blood itself, is evidently the far more important part of the office of the Liver, as regards the Respiratory function.

3. *The Kidneys.—Secretion of Urine.*

404. The *Kidneys* cannot be regarded as inferior in importance to the Liver, when considered merely as Excreting organs; but their function only consists in separating from the blood certain effete substances which are to be thrown off from it, and has no direct connection with any of the nutritive operations concerned in the introduction of aliment into the system. The following are the points in the minute structure of these organs, which are of most importance in their Physiological relations.* Their glandular and vascular elements are imbedded in a stroma composed of interlacing fibres (Fig. 68, *d d*); this is more abundant in the

Fig. 68



Section of the *Cortical Substance* of the *Human Kidney*.—A A, tubuli uriniferi divided transversely, showing the spheroidal epithelium in their interior; B, Malpighian Capsule; *a*, its afferent branch of the renal artery; *b*, its glomerulus of capillaries; *c c*, secreting plexus formed by its efferent vessels; *d d*, fibrous stroma.

medullary, than in the cortical substance; but at the surface of the gland it is condensed into a continuous membrane, which is loosely connected with the proper capsule. The distinction between the *cortical* and the *medullary* part of the Kidney essentially consists in this,—that the former is by far the most vascular, and the plexus formed by the tubuli uriniferi seems to come into the closest relation with that of the sanguiferous capillaries, so that it is probably the seat of the greater part of the process of secretion; whilst the latter is principally composed of tubes, passing in a straight line from the former towards their point

* See especially Mr. Bowman's Memoir in the "Philosophical Transactions," 1842; also Goodsir in "Edinb. Monthly Journal," 1842; Gerlach, Bidder, and Kölliker in "Müller's Archiv.," 1845; Toynbee in "Med.-Chir. Trans.," 1846; Johnson in "Cyclop. of Anat. and Phys.," art. 'Ren'; Gairdner in "Edinb. Monthly Journal," 1848; Frerichs, "Die Bright'sche Nierenkrankheit und deren Behandlung," 1851; and Kölliker, "Mikroskopische Anatomie," and "Man. of Hum. Histol." (Syden. Soc.)

of entrance into the ureter. The tubuli uriniferi, in passing outwards from the calices, increase in number by divarication to a considerable extent, as shown in Fig. 71, but their diameter remains the same. When they arrive in the cortical substance, their previously-straight direction is departed-from, and they become much convoluted. The closeness of the texture formed by their interlacement with the blood-vessels, renders it difficult to obtain a clear view of their mode of termination, but they seem to inosculate with each other, so as to form a plexus, with free extremities here and there (Fig. 71); the number of such free extremities, however, does not appear to be nearly equal to that of the uriniferous tubes themselves.* The tubuli are lined with an epithelium, the character of which varies in different parts of their course. In the tubes of the cortical substance, the cells are spheroidal in their form, and project considerably from the basement membrane on which they lie, so as to occupy a considerable part of the area (Fig. 68, A A), as is the case with those of glandular follicles generally. In the straight tubes of the medullary substance, on the other hand, the

FIG. 69.*

FIG. 70.†

* Portion of the *Kidney* of a new-born infant:—A, natural size; *a*, *a*, Corpora Malpighiana, as dispersed points in the cortical substance; *b*, papilla:—B, a smaller part magnified; *a*, *a*, Corpora Malpighiana; *b*, tubuli uriniferi.

† Portion of one of the *tubuli uriniferi*, from the Medullary substance of the kidney of an adult; showing its tesselated epithelium.

cells are flattened and polygonal, corresponding to the general type of pavement-epithelium (Fig. 70), and they project so little from the walls of the tube, as to occasion but little diminution in its area. Each cell contains a nucleus; and in its interior there is ordinarily to be seen a little finely-granular matter, with a few minute fat-globules clustered round the nucleus; the cell-wall is remarkable for its delicacy, and is

* In Mr. Bowman's opinion, *all* the free extremities of the tubuli uriniferi include Corpora Malpighiana; and the appearance of cæcal terminations, such as those represented at *a* and *c*, Fig. 71, he regards as an optical illusion, caused by a change in the direction of the tubuli, which occasions them to dip-away suddenly from the observer.

remain in the interior of the tubules. Scattered through the plexus formed by the blood vessels and uriniferous tubes, a number of little dark points may be seen with the naked eye, to which the designation of Corpora Malpighiana has been given, after the name of their discoverer. Each one of these, when examined with a high magnifying power, is found to consist of a convoluted mass of minute blood-vessels (Fig. 71, *g*); and this is included in a flask-like dilatation of one of the tubuli uriniferi (Figs. 68, B, 72, *c*, *c′*). According to Mr. Bowman, this dilatation proceeds only from the termination of the tubulus: and this seems to be usually the case, although it appears not improbable that it may sometimes be a lateral diverticulum, as described by Gerlach (loc. cit.). The epithelium, which elsewhere lines the tube, is altered in appearance where the tube is continuous with this capsular dilatation (Fig. 72, *b′*); being there more transparent, and furnished with cilia (as shown at *b″*), which, in the Frog and other Reptiles, may be seen for many hours after death, in very active motion, directing a current down the tube. Further within the capsule, this epithelium becomes excessively delicate, and sometimes disappears altogether. The surface of the Malpighian tuft is often seen to be studded with nuclear particles, which suggest the idea that it is covered by an epithelial layer; and hence Gerlach, followed by other anatomists, has maintained that the flask-shaped dilatation of the tubulus uriniferus is not perforated by the blood-vessels which form the Malpighian tuft, but is reflected over them. It appears probable, however, that these nuclear particles really belong to the walls of the vessels; and the most careful examination has failed to detect any such reflexion. On this as on all other points of importance, therefore, Mr. Bowman's original description proves to be unassailable.*

Fig. 72.

Uriniferous Tube, Malpighian Tuft, and Capsule, from *Kidney of Frog*:—*a*, cavity of the tube; *b*, epithelium of the tube; *b′*, ciliated epithelium of the neck of the capsule; *b″* detached epithelium-scale; *c*, basement membrane of tube; *c′*, basement membrane of capsule; *m*, convoluted capillaries of the Malpighian tuft.

405. The Circulation of Blood through the Kidney presents a very remarkable peculiarity. The supply is derived in Man (as in other Mammalia) direct from the *arterial* system; though in Fishes and Reptiles the urinary apparatus is connected, as well as the biliary, with the *portal venous* system, and even in Birds a portion of its blood is derived from

* The *à priori* improbability that the basement-membrane of a glandular tubule or follicle should be thus penetrated by blood-vessels, has been entirely removed by the discovery that such penetration does take place in other cases, as the Peyerian glandulæ (§ 133) and the Corpora Malpighiana of the Spleen (§ 142 II).

the latter. But although this organ is supplied from the Renal Artery yet it is not to its proper secretory apparatus that the blood of the artery is distributed in the first instance; for, on entering the kidney, the vessel speedily and entirely divides itself into minute twigs, which are the *afferent* vessels of the Malpighian tufts (Figs 68, *a*, 73, *af*). After it has pierced the capsule, each twig dilates; and suddenly divides and sub-divides itself into several minute branches, terminating in convoluted capillaries, which are collected in the form of a ball (Figs. 68, *b*, 73, *m m*); and from the interior of the ball, the solitary *efferent* vessel *e f*, arises, which passes out of the capsule by the side of the single afferent vessel. The tuft seems to lie loose and bare in the capsule, being attached to it only by its afferent and efferent vessels (Fig 68, *b*). The *efferent* vessels, on leaving the Malpighian bodies, separately enter the plexus of capillaries, (Figs. 68, *c*, 73, *p*) surrounding the tubuli uriniferi (*st*), and supply that plexus with blood; from this plexus the renal vein arises. Thus there is a striking analogy between the mode in which the tubuli uriniferi are supplied with blood, for the purpose of elaborating their secretion, and the plan on which the hepatic circulation is carried on. For as the secretion of the Liver is formed from blood conveyed to it by one large vessel, the portal vein, which has collected it from the venous capillaries of the chylopoietic viscera, and which subdivides again to distribute it

Fig. 73.

Distribution of the Renal vessels, from Kidney of Horse. *a*, branch of Renal artery; *af*, afferent vessel; *m*, *m*, Malpighian tufts; *ef*, *ef*, efferent vessels; *p*, vascular plexus surrounding the tubes; *st*, straight tube; *ct*, convoluted tube.

through the liver, so the secretion of the Kidney is elaborated from blood which has already passed through one set of capillary vessels, those of the Malpighian tufts; this blood is collected and conveyed to the proper *secreting* surface, however, not by one large trunk (which would have been a very inconvenient arrangement), but by a multitude of small ones, the *efferent* vessels of the Malpighian bodies, which may be regarded as collectively representing the portal vein, since they convey the blood from the systemic to the secreting capillaries. Hence the Kidney may be said to have a *portal* system within itself.—This ingenious view of Mr. Bowman's finds support from the fact, that in Reptiles the *efferent* vessels of the Malpighian bodies (which receive their blood, as elsewhere, from the renal artery) unite with the renal branches of the Vena Portæ to form the secreting plexus around the tubuli uriniferi. Here, therefore, the blood of the secreting plexus has a double source, the vessels which supply it receiving their blood in part from the capillaries of the organ itself, and in part from those of viscera external to it; just as, in the Liver, the secreting plexus is supplied in part by the nutritive capillaries of the organ itself, which receive their blood from the hepatic artery, and in part by the blood conveyed from the chylopoietic viscera through the vena portæ.

406 These admirable researches of Mr. Bowman on the structure of the Malpighian bodies, and on the vascular apparatus of the Kidney

have thrown great light upon the mode in which the Urinary secretion is elaborated. One of the most remarkable circumstances attending this excretion, in the Mammalia particularly, is the large but variable quantity of *water*, which is thus got-rid-of,—the amount of which bears no constant proportion to that of the solid matter dissolved in it. The Kidneys, in fact, seem to form a kind of regulating valve, by which the quantity of water in the system is kept to its proper amount. The amount of exhalation from the Skin, which, with that from the Lungs, is the other principal means of removing superfluous liquid from the blood, is liable to be greatly affected by the temperature and degree of humidity of the air around (§ 422): hence, if there were not some other means of adjusting the quantity of fluid in the blood vessels, it would be subject to continual and very injurious variation. This important function is performed by the Kidneys; which allow such a quantity of water to pass into the urinary tubes, as may keep the *pressure* within the vessels at a nearly uniform standard. The quantity of water which is passed-off by the Kidneys, therefore, will depend in part upon that exhaled by the Skin; being greatest when this is least, and *vice versâ:* but the quantity of solid matter to be conveyed-away in the secretion, has little to do with this; being dependent upon the amount of *waste* in the system, and upon the quantity of surplus azotized aliment which has to be discharged through this channel.—The Kidney contains two very distinct provisions for these purposes. The *cells* lining the tubuli uriniferi are probably here, as elsewhere, the instruments by which the *solid* matter of the secretion is eliminated; whilst it can scarcely be doubted, that the office of the Corpora Malpighiana is to allow the transudation of the superfluous fluid through the thin-walled and naked capillaries of which they are composed. "It would indeed," Mr. Bowman remarks (loc. cit., p. 75), "be difficult to conceive a disposition of parts more calculated to favour the escape of water from the blood, than that of the Malpighian body. A large artery breaks-up in a very direct manner into a number of minute branches; each of which suddenly opens into an assemblage of vessels of far greater aggregate capacity than itself, and from which there is but one narrow exit. Hence must arise a very abrupt retardation in the velocity of the current of blood. The vessels in which this delay occurs, are uncovered by any structure. They lie bare in a cell, from which there is but one outlet, the orifice of the tube. This orifice is encircled by cilia, in active motion, directing a current towards the tube. These exquisite organs must not only serve to carry forward the fluid which is already in the cell, and in which the vascular tuft is bathed; but must tend to remove pressure from the free surface of the vessels, and so to encourage the escape of their more fluid contents."—Here we see the essential difference which exists, between the *vital* agency concerned in the true Secreting process, and the *physical* power which occasions fluid exhalation or transudation. This difference is precisely the same as that which exists between the *vital* act of selective absorption, and the *physical* operation of endosmose or imbibition. By Imbibition and Transudation, certain fluids may pass through organic membranes, in the dead as well as in the living body; and this passage depends merely upon the physical condition of the part, in regard to the amount and the nature of the fluid it contains, and the permeability of its tissues. Not only does

water thus transude, but various substances that are held in complete solution in it, especially albuminous and saline matter. It is in this manner that the Blood absorbs fluids from the digestive cavity (§ 124) and pours-out the serous fluid which occupies the interspaces of the areolar tissue and the serous cavities. The transudation of the watery portion of the blood is much increased by any impediment to its flow through the vessels, and also by any causes that produce a diminished resistance in their walls.

407. The Kidney is liable to undergo alterations of its normal structure, from a perversion of its ordinary formative processes, which are of a nature very analogous to those which have been already described as occurring in the Liver, though with differences arising out of the specialities of its conformation. Several different kinds, as well as degrees of such alteration, have been described (as it now appears) under the general term 'Bright's disease,' which has been applied almost indiscriminately to almost every kind of chronic degeneration of the structure of the Kidney, that is attended with the presence of albumen in the urine.—In the first place, there may be mere vascular *Congestion*, this especially affecting the vascular coil of the Malpighian bodies, and the secreting plexus around the tubuli uriniferi of the cortical substance; with this, however, there is usually more or less effusion, either of blood or of fibrinous exudation, into the interior of the tubules, and sometimes amidst the interstitial tissue; and the epithelium is very commonly thrown-off, sometimes presenting itself in the urine, but often remaining entangled in the fibrinous exudation, so as to block-up the tubuli. This condition may be induced by cold, and also by scarlatina, as well as by other cutaneous affections which interfere in a considerable degree with the ordinary functions of the skin.—When this congestion passes into *Inflammation*, the effusion becomes more completely organizable; and in the changes which this subsequently undergoes, it becomes the occasion of a further alteration in the proper substance of the kidney. The seat of the plastic exudation may be either the inter-tubular substance, or the interior of the tubuli. In the first case, it usually becomes developed into a more or less perfect fibrous tissue, which, by undergoing a progressive contraction, comes to press-upon, and at last to obliterate, many of the blood-vessels and tubuli uriniferi; thus producing a deficient supply of blood, and atrophy of the proper tissue of the Kidney, whilst the bulk of the organ is generally augmented by the large proportion of exudation-tissue which it may include, though it is sometimes reduced. This state is analogous in all essential particulars to the cirrhosis of the Liver (§ 396). The plastic exudation, on the other hand, may be poured-out rather *within* than around the tubes, thus directly blocking them up. In either case, however, an obstruction to the exit of the secreted fluid through any tube, whilst its Malpighian corpuscle is still capable of allowing the transudation of fluid through its glomerulus, will occasion a distension of the tube or of its Malpighian capsule above the obstruction; and thus a cyst is formed, which may itself become filled with exudation-substance. When the exudation is poured-out into the interior of the tubuli, it seems to be much more prone to degenerating changes, than when it is effused into the intertubular substance; for it seldom passes into the fibrous condition, but at first presents a granular

appearance, and speedily undergoes 'fatty degeneration.' And this is not unfrequently the case also with the interstitial deposit, which is often formed in greater or less abundance when the interior of the tubes is also occupied by it, so that the morbid product is found in all parts of the gland,—the intertubular tissue, the tubules, and the Malpighian capsules, —obliterating a large proportion of the normal structure. This condition presents itself, more or less fully developed, in the greater number of fatal cases of 'Bright's disease;' and it is that which first attracted attention as 'granular degeneration,' the granulations being produced by the distension of loops or clusters of tubules with exudation-matter.—It is probable that in the case of the Kidney, as in that of the Liver, there is an idiopathic 'fatty degeneration' of the secreting cells (§ 397), without any exudation; and this may become a source of corresponding perversion in the character of the urinary secretion.*

408. It must not be supposed, however, that any of the lesions now described are invariably coincident with the presence of Albumen in the Urine: for it has been fully proved, on the one hand, that albumen may present itself in this excretion, without any alteration in the structure of the kidney, and, on the other, that various forms of Bright's disease may exist, even in an advanced stage, without any albumen being detectable in the urine.† These variations may probably be attributed to two classes of conditions, viz., the state of the albumen in the blood itself, and the state of the capillary circulation in the kidney. We have seen that the weak form of albumen which is first taken-up by absorption from the alimentary canal, is distinguished by its proneness to transudation (§ 183); whilst, on the other hand, the strong albumen of the egg, if injected into the systemic blood-current, finds its way out again by the urine, as a foreign substance (§ 132); an assimilating action being required, in the case of each, to give it the normal characters of blood-albumen. It is probably, in part at least, to the want of such perfect assimilation of the newly-absorbed albumen, that we are to attribute the increase of albumen in the urine passed soon after meals, by patients suffering under Bright's disease; something, however, may be due to the simple augmentation of the bulk of the blood, and especially of its solids. But, again, it has been shown that any cause which produces congestion of the vessels of the kidney, favours the passage of the normal albumen of the blood into the urine;‡ and thus we see how albuminous urine may be produced by the repulsion of blood from the cutaneous surface to the kidney, or by the determining influence of cantharides or other irritant diuretics, or by any obstruction to the return of blood from the capillary plexus by the renal veins. Now it seems quite conceivable, that, in by far the larger proportion of cases, the pressure of an abnormal deposit should be exercised in impeding the *venous* rather than the arterial circulation in the kidney; and this would well account for the very general presence of albumen in the urine, in these morbid conditions of the secreting organ. But, on the

* In the foregoing account of the pathological changes in the Kidney, which constitute 'Bright's Disease,' the views of Frerichs (in his admirable treatise "Die Bright'sche Nierenkrankheit und deren Behandlung") have been chiefly followed.

† See Dr. Begbie in the "Brit. and For. Med.-Chir. Rev.," vol. xii. p. 16.

‡ See Robinson in "Med.-Chir. Transact.," vol. xxvi. p. 51.

other hand, it is no less conceivable that the *arterial* current might sometimes be the one chiefly obstructed, so that there would be the very opposite to a state of congestion in the capillaries and Malpighian glomeruli; and it may be in such cases as these, that the ordinary symptom of Bright's disease is wanting.

409. The nature and purposes of the Urinary secretion, and the alterations which it is liable to undergo in various conditions of the system, are much better understood than are those of the Bile; this is owing, in great part, to the two circumstances, that it may be readily collected in a state of purity, and that its ingredients are of such a nature as to be easily and definitely separated from each other by simple chemical means. There can be no doubt that the chief purpose of this excretion is to remove from the system the effete *azotized* matters, which the blood takes-up in the course of its circulation, or which may have been produced by changes occurring in itself. This is evident from the large proportion of Nitrogen in the solid matter dissolved in the urine, and from the crystalline form presented by much of this solid matter when separated,—a form which indicates that its state of combination is such as to prevent it from conducing to the nutrition of the system. The injurious effects of the retention of the components of the Urinary secretion in the Blood, are fully demonstrated by the results of its suppression; whether this be made to take place experimentally (as by tying the renal artery), or be the consequence of a disordered condition of the kidney. The symptoms of *Uræmia* (as this condition has been appropriately termed) are altogether such as indicate the action of a specific poison upon the Nervous system; affecting either the Brain or the Spinal Cord separately, or both together. In the first form, a state of stupor comes on rather suddenly, out of which the patient is with difficulty aroused; and this gradually deepens into complete coma, with fixed pupils and stertorous breathing, just as in ordinary kinds of narcotic poisoning. In the second form, convulsions of an epileptic character, frequently affecting the whole muscular system, suddenly occur; but there is no loss of consciousness. In the third form, coma and convulsions are combined.—It has been generally supposed that these results are attributable to the accumulation of *urea* in the blood; but clinical observation affords sufficient evidence, that there is no constant relation between the severity of these symptoms and the amount of urea in the circulating system;* and experiment has determined that the other constituents of the urine do not exert any more potent influence.† It seems probable, then, that some substance formed at the expense of the normal constituents of urine, rather than either of these substances themselves, is the real poisonous agent in cases of Uræmia; and very cogent evidence has been adduced by Prof. Frerichs, in proof of his idea that the symptoms of this disorder arise from the conversion of the Urea in the circulating current into Carbonate of Ammonia, by the

* It has been remarked by Bright, Christison, G. O. Rees, and Frerichs, that urea may often be obtained in considerable quantity from the blood of patients suffering under 'Bright's disease,' who were at the same time free from all nervous symptoms.

† Thus Frerichs, as Bichat, Courten, and Gaspard had before done, repeatedly injected from 20 to 40 grammes of filtered human urine, sometimes even with the addition of urea, into the veins of animals, without any ill effects resulting.

agency of a suitable ferment; so that, however great may be the accumulation, it does not give rise to any serious consequences, unless this ferment be also present. Two series of experiments are described by him as supporting this doctrine; the first showing that in cases of uræmic intoxication, a resolution of urea into carbonate of ammonia is actually taking place, ammonia being found in the expired air when the first symptoms make their appearance, and in the blood and in the contents of the stomach after death;* and the second proving that the injection of carbonate of ammonia into the circulating current induces a train of symptoms essentially corresponding with those of uræmia, stupor and convulsions occurring either separately or conjointly.†—It seems not improbable that, as in the case of the retention of Bile in the Blood (§ 401), many of the minor as well as of the severer forms of sympathetic disturbance, connected with disordered secretion from the kidney, are due to this directly-poisonous operation of the decomposing constituents of the urine, upon the several organs whose function is disturbed; and that many complaints, in which no such agency has been until recently suspected,—especially Convulsive affections, arising from a disordered action of the nervous centres,—are thus due to the insufficient elimination of Urea from the Blood.

410. In order to form a correct opinion of the state of the Urinary secretion in morbid conditions of the system, it is desirable to be acquainted with every leading particular regarding its normal character.—Fresh healthy Urine is a perfectly-transparent, amber-yellow-coloured liquid, exhaling a peculiar but not disagreeable odour, and having a bitterish saline taste. The only morphological elements which it normally contains, are pavement epithelium-cells and mucus-corpuscles from the lining of the urinary passages; which, however, are present in

* It is the conclusion of MM. Bernard and Barreswil, from the experiments which they have performed to determine, why, after the extirpation of the kidneys, a period of from twenty-four to forty-eight hours always elapses, before the blood shows any decided traces of Urea,—that, under such circumstances, the urea is eliminated by the secretions of the intestinal tube, and chiefly by the gastric juice, in the form of an ammoniacal salt, and that no urea can be detected in the blood, until, by a progressive diminution of the vital powers, the intestinal fluids become more and more diminished in quantity, and the metastatic channels for the elimination of urea are closed. Retention of urea in the blood, as they argue, is thus a result, not directly of the suppression of urine, but rather of the loss of vigour which follows it. ("Archiv. Génér. de Medecine," 4ieme Sér., tom. xiii., p. 449.)—On the *metastasis* of the Urinary excretion, see § 387.

† On this subject, see the Chapter on 'Uræmia' in the Treatise of Frerichs just cited. His conclusions, however, though quite in harmony with the observations of Lehmann ("Physiological Chemistry," translated by Dr. Day, vol. ii., p. 253), have been disputed by other pathologists, as by Zimmermann, "Deutsche Klinik," No. 37, and "Brit. and For. Med. Chir. Rev.," vol. xi., p. 209, and by Schottin, "Vierordt's Archiv.," 1853, heft i., p. 170, and "Brit. and For. Med. Chir. Rev.," vol. xii., p. 268. The latter of these critics affirms, that the cause of the symptoms of uræmic poisoning, in cases of advanced 'Bright's disease,' "must be looked for in an impediment of the metamorphosis of the tissues, in a destruction of the process of endosmose and exosmose between blood and tissues, and perhaps in a generally-diminished oxidation-power in the blood."—It is difficult, however, to believe that the narcotic symptoms following upon sudden and complete suppression of the urinary excretion, with accumulation of urea in the blood (as shown by analysis), and abating with the elimination of the urea by the re-establishment of the secretion (as happened in the interesting case recorded by Dr. Shearman in the "Edinb. Monthly Journal," March, 1848), can be due to anything else than the direct toxic influence of the urea, or of some product of its metamorphosis.

healthy urine to but a very small amount. But in certain morbid states of the urine, minute cylindrical bodies are seen, in greater or less abundance, which are obviously derived from the tubuli uriniferi. These are sometimes composed almost exclusively of the epithelial lining of the tubes, of which the cells remain adherent to each other, notwithstanding their detachment from the basement-membrane beneath; whilst sometimes they are fibrinous moulds of the interior of the tubes, formed by exudation of plastic material, and containing blood- or pus-corpuscles; and in other instances, again, they seem to consist of nothing else than the basement-membrane of the tubes themselves. The first of these forms occurs chiefly in desquamative irritation of the kidneys; the second as a consequence of acute inflammation, and the last in the advanced stages of 'Bright's disease.'—In all natural conditions of the Human system (even when a vegetable diet is used), the urine possesses a well-marked acid reaction. When it is left to itself for some time, slight nebulæ, consisting of mucus, are formed in it; and these gradually descend to the bottom. Soon afterwards, an unpleasant odour is developed; instead of an acid, an alkaline reaction is presented, in consequence of the decomposition of the urea into carbonate of ammonia; and a precipitation of earthy phosphates then takes place. A turbidity may be produced, however, by the precipitation of urates of soda and ammonia, on the simple cooling of the urine, without any such departure from its normal composition as would properly constitute disease, but under some of the conditions hereafter to be specified (§ 412). But if the urine be turbid, when it is first passed from the body, and has a temperature of 98° or 100°, it must be considered as abnormal.—The average *Quantity* of urine passed during the 24 hours, has been variously estimated; it differs, of course, with the amount of fluid ingested, and it is influenced also by the external temperature, a much smaller amount of the superfluous fluid of the body being set-free from the skin in winter than in summer, and a larger proportion being carried-off by the kidneys. Probably we shall be pretty near the truth, in estimating the amount (with Dr. Prout) at from about 30 oz. in summer, to 40 oz. in winter, for a person who does not drink more than the simple wants of nature require. —The *Specific Gravity* comes to be a very important character, in various morbid conditions of the urine, and it is therefore desirable to estimate it correctly. This also is of course subject to the like causes of variation; since, when the same amount of solid matter is dissolved in a larger or smaller quantity of water, the specific gravity will be proportionably lower or higher; or, the quantity of water remaining the same, an increase or diminution in the amount of solid matter will raise or lower the specific gravity. It has been commonly supposed that the amount of solid matters in the urine bears such a constant ratio to its specific gravity, that the former may be approximatively deduced from the latter: this, however, has been clearly shown to be by no means the case.* Still, the determination of the specific gravity is of sufficient importance for diagnostic purposes, to make it desirable to possess an average standard, as nearly approaching to accuracy as circumstances will permit. The average, according to Dr. Prout, in a healthy person,

* See "Lehmann's Physiological Chemistry," (Cavendish Society), vol. ii. p. 436.

taking the whole year round, is about 1020; the standard rising in summer (on account of the greater discharge of fluid by perspiration) to 1025; and being lowered in winter to 1015. Simon, however, states the average specific gravity at no more than 1012. It will mainly depend, in each individual case, upon the amount of azotized solids and of aqueous fluids habitually ingested, allowing for the portion of the latter that is dissipated by cutaneous exhalation, and it will also vary with the period that has elapsed since the last introduction of liquid into the stomach. From these and other causes, the amount of solid matter in 1000 parts of Urine may vary from 20 to 70 parts; and hence the various recorded analyses of this liquid present very wide diversities in the proportions of its solid constituents.* These discrepancies, however, being chiefly due to the fluctuating amount of water, become very much less (as Simon pointed out) when we calculate the proportion which each principal component bears to 100 of solid residue, as is shown in the following Table.—

	Berzelius	Lehmann	Simon	Marchand
Urea	45·10	49·68	33·80	45·91
Uric acid	1·50	1·61	1·40	1·59
Extractive matter, Ammonia-salts, and Chloride of Sodium	36·30	28·95	42·60	32·49
Alkaline Sulphates	10·30	11·58	8·14	10·18
Alkaline Phosphates	6·88	5·96	6·50	4·57
Phosphates of Lime and Magnesia	1·50	1·97	1·59	1·81

We shall presently find the causes of some of the variations even here shown, to be in the nature of the ingesta, and in the amount of exercise taken by the individual.

411. The most important of those organic constituents of the Urine, whose presence may be directly traced to the metamorphosis of the azotized components of the tissues and of the blood (§ 348), is evidently that which, from its being the principal source of the characteristic properties of the secretion, is termed *Urea*. This substance, as already mentioned (§ 172), exists preformed in the Blood, though ordinarily in very small amount; being generated by the retrograde metamorphosis of the azotized tissues, especially the Muscular (and in this probably through the intermediation of creatine or of uric acid), and also by similar changes in the unassimilated portions of the Blood itself.—The amount of Urea excreted in the 24 hours has been made the subject of examination by numerous Chemists: the following are the results deduced by M. Lecanu† from a series of 120 analyses:—

	Minimum	Mean	Maximum
By Men	357·51 grs.	433·13 grs.	510·36 grs.
By Women	153·25 ,,	296·15 ,,	437·06 ,,
By Old Men (84 to 86 years)	61·08 ,,	125·22 ,,	295·15 ,,
By Children of eight years	161·78 ,,	207·99 ,,	254·20 ,,
By Children of four years	57·28 ,,	69·55 ,,	81·83 ,,

The averages obtained by Scherer, Bischof, and other subsequent experi

* It is remarked by Lehmann (Op. cit., p. 447), that the urine of the French is poorest in solid constituents, especially in urea and uric acid, and that of the English the richest, that of the Germans being intermediate between the two, the ratio in each nation being in conformity with the proportion of animal food entering into its ordinary diet.

† "Journal de Pharmacie," tom. xxv.

menters, are very closely conformable to these (allowance being made for the difference of habitual diet already referred-to, § 410); and their observations all agree, moreover, in assigning a like high proportion to the excretion of urea in children, as compared with the weight of their bodies. Thus Scherer* states that whilst an adult, for every 1 lb. weight (avord.) of his body, daily excretes 2·94 grains of urea, a child excretes 5·67 grains of urea for every 1 lb. weight of his body. This excessive proportion of urea in young subjects may be considered as dependent on the rapidity of interstitial change in their tissues, while the reverse of this is true of aged subjects. (See CHAP XVIII.) The quantity of Urea secreted at any given period of life, seems to depend mainly on two conditions, namely, the degree of muscular exertion previously put forth, and the amount of azotized matter ingested as food. Thus Prof. Lehmann ascertained that, by the substitution of *violent* for *moderate* exercise, the quantity of Urea was raised from $32\frac{7}{8}$ to $45\frac{1}{4}$ parts; and Simon found that, by two hours' violent exercise, the proportion of the urea in the urine passed half an hour subsequently, was double that contained in the morning-urine. Again, Prof. Lehmann has shown (§ 417) that the amount of Urea excreted daily, when no azotized matter was taken-in as food, and when the excretion was simply a measure of the 'waste' of the tissues, was not above *half* that excreted when an ordinary mixed diet was employed, and only about *two-sevenths* of that which was passed when the diet was purely animal. The recent experiments of Prof. Bischof are to the same effect, for he found that a large dog secreted, with mixed food, from 230 to 300 grains of urea daily; with flesh diet, 802 grains, and when fed on intestines and gelatine, no less than 1110 grains daily. This last statement confirms the inference to which the injection of a solution of Gelatin directly into the blood appears to lead (§ 51); namely, that urea may be formed directly from the metamorphosis of this substance, and probably, therefore, from the disintegration of the gelatigenous as well as of the albuminous tissues. The observations of Bidder and Schmidt upon the quantity of urea excreted by a cat fed exclusively upon fat meat in varying proportions, led them to conclude that this animal separates by the kidneys 6·8 parts of urea for every 100 parts of flesh which it consumes, this amount of urea containing about six-sevenths of the nitrogen contained in the food. The metamorphosis of tissue would seem to proceed in Carnivorous animals at a far more rapid rate than in Man; for this cat excreted on an average as much as 14·77 grains of urea for every 1 lb. (avord.) weight of its body, even when inanitiated; whilst, if highly fed with flesh, it excreted no less than 53·62 grains daily, for every 1 lb. weight of its body.—The foregoing facts seem to afford full confirmation to the doctrine already stated (§ 381), and advanced by the Author many years ago,† that the amount of urea in the urine can only be regarded as a measure of the metamorphosis of tissue, when no more food is ingested than is required to compensate for that metamorphosis; any histogenetic matter which escapes assimilation through not being required in the system, being normally decomposed, and its azotized

* "Verhandl. d. phys. med. Ges. zu Wurzburg," band ii. pp. 280-290.
† "Brit. and For. Med. Rev." vol. xv. p. 503.

portion eliminated through this channel.*—The amount of urea excreted daily, is usually (though not constantly) increased in febrile diseases; and when it is borne in mind that comparatively little food is taken under such circumstances, the increase must be wholly set-down to the account of the more rapid wasting of the tissues. In fact, an absence of increase, or even a certain amount of diminution, when the supply of food has almost entirely ceased, would still indicate an excess of 'waste.' Some valuable observations on this point have been recently made by Dr. A. Vogel;† who has found that in a case of typhoid fever, no less than 1065½ grains of urea were excreted daily (or nearly double the usual average for Germany, which is stated by Prof. Bischof at 540½ grains), and in a case of pyæmia, the extraordinary quantity of 1235½ grains. When the fever is over, the quantity of urea falls below the normal amount, in spite of the augmented quantity of nitrogenous food ingested, which is doubtless appropriated to the repair of the wasted tissues, and it then, after perfect recovery, returns to the physiological standard.

412. Next in importance to Urea, among the organic products of the metamorphosis of the azotized constituents of the tissues or of the blood, but ordinarily bearing a very small proportion to it in quantity, is *Uric acid.* The formation of this substance is probably anterior to that of urea; and we shall see that its proportion in the urine is augmented under the same conditions as regards *food* (§ 417). On the other hand, there is reason to think that *exercise*, by augmenting the respiration, tends to diminish the proportion of uric acid in the urine, by converting it into urea whilst yet in the circulating current; for this conversion may be effected by boiling it with peroxide of lead, which, by yielding oxygen, causes the resolution of uric into urea and oxalic acid, the latter being converted by a further process of oxidation into carbonic acid. The circumstances that most favour the *genesis* of uric acid in the system, therefore, and the *increase of its proportion in the urine* if there be no obstacle to its elimination, are a highly-azotized diet and inactive habits; whilst the reduction of the azotized portion of the diet to what is really wanted for the nutrition of the system, and the promotion of the respiration by active exercise, tend to reduce the proportion of this component. The *precipitation* of uric acid (usually in combination with soda or ammonia, or both), which frequently takes place on the cooling of the urine, must not be regarded as indicative of the presence of an unusual amount of this substance; since it may depend upon other conditions. It seems to have been clearly proved by Dr. Bence Jones,‡ that there is no relation whatever between the *acidity* of the urine, and the *absolute amount* of Uric acid which it may contain; for in the urine which is most acid, and which deposits the largest uric-acid sediment, very little uric acid may really exist; whilst that which contains most uric acid may hold it in perfect solution, and may have but a feeble acid reaction. The main cause of the deposit of Uric-acid sediments, is doubtless the presence of some other acid; for the addition of any acid to healthy

* See a valuable article on "The Metamorphosis of Tissue," giving an account of the researches of Bidder and Schmidt, Bischof, and others, in relation to the *genesis* of the solids of the Urine, in "Brit. and For. Med. Chir. Rev.," vol. xiii. p. 384.

† "Zeitschrift fur Ration. Med.," band iv. heft 3.

‡ See his 'Contributions to the Chemistry of the Urine,' in "Philos. Trans.," 1849.

urine passed soon after food, is always sufficient to produce it. But the deposit takes place less readily if the temperature of the fluid be high, since the solvent power of the acid phosphate of soda is then more strongly exerted; so, on the other hand, a deposit often takes place in urine which would not otherwise exhibit it, through an unusual reduction in its temperature, as by exposure to the cold air of a sleeping-room in the winter. Again, the deposit of uric-acid sediment is favoured by concentration of the liquid, which thus augments the proportion of the urate to the water, and at the same time intensifies the acid reaction; and thus urine whose constituents are otherwise normal, may throw down a copious deposit of this kind, merely from deficiency of water; whilst an unusual amount of uric acid may be really present without being deposited,—the urine, too, exhibiting its ordinary acidity,—if the proportion of water be large. Thus the uric-acid sediment may be regarded as dependent upon three concurrent conditions;—(1) Decrease of temperature; (2) Increased proportion of uric-acid compound to the water, positively or relatively; (3) Increased acidity of the urine. Sometimes one condition is most influential, sometimes another; but they are all usually concerned in some degree.—There are many diseases, especially those of a febrile nature, in which the presence of an *excess* of uric acid is a very marked symptom; there is often, at the same time, a reduction in the proportion of urea; and thus it would seem that, with perhaps an augmented tendency to disintegration of the tissues, there is an incapacity for the performance of that higher process of oxidation which is requisite for the genesis of urea, so that a larger proportion of the products of the 'waste' passes-off in the state of uric-acid, as in animals whose respiration is feeble.—This view derives support from the fact that *Hippuric acid*, which is only to be found in extremely minute proportion in healthy Human urine, and the large proportion of carbon in which indicates that it is to be regarded as a result of very imperfect oxidation, undergoes a marked increase under the same circumstances, and especially when obstructed action exists in either of the other great emunctories, so that a larger amount of carbonaceous matter is thrown upon the kidneys for elimination; for in this case, also, there is a deficiency in the normal amount of urea.—Hence, wherever there is an actual excess of Uric acid in the system, constituting the true 'uric acid diathesis,' *diet*, *exercise*, and the promotion of the *other excretions*, afford the most effectual means of controlling it.

413. Although the presence of *Creatine* and *Creatinine* in the Urine, the former in very small proportion, but the latter in considerably larger amount, is now a well-established fact, the actual quantities ordinarily excreted, and the circumstances which favour their increase and diminution, have not yet been determined. From the ready convertibility of Creatine into Creatinine and Urea, and from the fact that in the 'juice of flesh' there is far more of Creatine than of Creatinine, whilst in the Urine the proportions are reversed, it seems likely that Creatine is one of the first products of the disintegration of muscular tissue, and that a portion of the urea eliminated in the urine, as well as the greater part (if not the whole) of the creatinine, is generated at its expense. The presence of *Lactic acid* in the Urine, although by no means infrequent, must be regarded as exceptional. A constant genesis of this substance is taking

place in the body, not merely as a product of the metamorphosis of the saccharine matters employed as food, but also as one of the results of the disintegration of the azotized tissues; but the respiratory process affords the ordinary channel for its removal; so that it is only when its production is excessive, or when there is some obstruction to its elimination by the lungs, that it makes its appearance in the urine. These conditions are so often present in disease, that Lactic acid is far more commonly present in abnormal than in normal states of the secretion.—The *Extractive Matters* of the Urine are made-up of a variety of different compounds, our knowledge of which is gradually being extended. Among the substances which rank under this head in the ordinary analyses of Urine, are creatine, creatinine, and hippuric acid; and others are being successively determined. Thus Stadeler has shown that the 'extractive' of the Urine of the Cow contains a peculiar azotized compound, and several volatile non-azotized acids, analogous to, and in one instance absolutely identical with, the products of the imperfect oxidation of wood or coal.* And Prof. Ronalds has shown, that the 'extractive' of Human urine ordinarily contains a sulphurized and a phosphorized compound, which serve for the excretion of sulphur and phosphorus in an unoxidized state.† The *Urine-Pigment*, again, has been to a certain extent separated as a definite compound from the 'extractive,' especially by the researches of Heller,‡ and although there is still much uncertainty as to its precise character (whether, for example, it is composed of two or more distinct substances), there is no doubt as to the very large proportion of carbon it contains; this element constituting as much as 58½ per cent. of the ordinary pigment, 62½ per cent. of the substance termed purpurine, which is generated by the action of hydrochloric acid on urine-pigment, and even 65½ per cent. of the colouring matter of the urine of patients suffering under febrile disorders or organic disease of the liver, in which bile-pigment often passes into the urine.§—On the whole, we may say that with the exception of Creatine and Creatinine, all the known constituents of the 'Urinary extractive' are substances which are rich in carbon and comparatively poor in nitrogen, so that their increase will be favoured by an excess of carbonaceous food, an imperfect action of the liver, and a low degree of respiration; whilst, on the other hand, a highly-azotized diet, especially if combined with active exercise, will tend to their reduction.

414. Besides its organic materials, the Urine contains a considerable amount of *Saline* matter; the excretion of which, in a state of solution, appears to be one of the principal offices of the Kidney. Various saline compounds are being continually introduced with the food; and others are formed within the system, by the oxidation of the Sulphur and Phosphorus of the tissues or of the food, and by the combination of the sulphuric and phosphoric acids thus formed, with alkaline and earthy bases which the food may contain, usually in a state of combination with weaker acids which are otherwise disposed of. Thus the Saline compounds found in the urine, are to be regarded as partly proceeding from

* See Dr. Gregory's "Handbook of Organic Chemistry," p. 450.

† See "Philosophical Transactions," 1846, pp. 461-464.

‡ "Arch. fur Chemie und Mikrosk.," band ii. pp. 161, 173.

§ See Dr. Golding Bird's 'Lectures on Therapeutics,' in "Med. Gaz.," 1848, vol. xlii. p. 229.

the retrograde metamorphosis of the materials of the tissues, after these have served their purpose in the economy, and partly from that of such components of the food, as, being superfluous, do not undergo organisation. But the Kidney also serves as the channel for the elimination of saline compounds introduced into the system *per se*, these being sometimes normally present in the body, but ingested in too large an amount, as is often the case with common Salt; whilst, on the other hand, they may be altogether foreign to the composition alike of its solids and its fluids. —The *Alkaline Sulphates* usually constitute, as we have seen (§ [illegible]), about 10 per cent. of the whole solid matter of the Urine. Being always in solution, however, they never make their presence known by the formation of sediments, and are only to be detected by chemical tests. The causes which influence their amount have been carefully studied by Dr. Bence Jones; who has shown that they vary (like urea) with the amount of food ingested, and with the degree of nervo-muscular activity put forth; as might be anticipated from the fact, that, under ordinary circumstances, the sulphuric acid is entirely formed within the system, by the oxidation of the sulphur of the protein-compounds, the bases being furnished by the alkaline carbonates or phosphates of the blood. When sulphuric acid or soluble sulphates are taken into the system *per se*, they partly find their way out of it by the Kidneys; the proportion of sulphuric acid in the urine being for a time augmented, although the increase is not considerable until some hours have elapsed after the introduction of these substances into the stomach.*—The amount of *Alkaline Phosphates* in the Urine is usually about half that of the alkaline sulphates. The acid of these also is ordinarily generated within the system, by the oxidation of the phosphorus originally introduced in the protein-compounds; and thus, as in the case of the sulphates, the quantity of them which is excreted by the urine bears a certain relation to the amount of these compounds ingested as food, and also to the amount of muscular tissue which has undergone disintegration by exercise. But it further appears that there is a special relation between the quantity of the alkaline phosphates in the urine, and the amount of disintegration of the *nervous* tissue; as might have been suspected from the fact, that this tissue is distinguished by the very large proportion of phosphorus, united with fatty acids, which it contains. And a marked increase of these salts is observed in those inflammatory diseases of the brain, in which there is reason to believe that an unusually-rapid disintegration of its texture is taking place.†—The *Earthy Phosphates* usually bear but a small proportion to the Alkaline; but their presence in the urine comes to be of great importance, with reference to the precipitates which they form in particular conditions of that secretion. From the researches of Dr. Bence Jones (loc. cit.) it appears, that the quantity of these phosphates in the urine chiefly varies with the amount of them contained in the food, into many

* Dr. Bence Jones in "Philosophical Transactions," 1849.

† See Dr. Bence Jones's valuable series of Papers in the "Philosophical Transactions" for 1845, 1847, and 1850, and in the "Medico-Chirurgical Transactions" for [illegible] and 1850. It is curious to observe, that whilst the increase in the alkaline phosphates in Inflammatory affections of the nervous centres is very marked, there appears to be a positive diminution of them in Delirium Tremens. A certain allowance must be made, however, for the abstinence from food, which will of itself occasion a reduction in the quantity excreted.

articles of which they enter largely; but he has also ascertained that their formation within the system is determined by the presence of their bases; for if any earthy salt, a little chloride of calcium or sulphate of magnesia for instance, be taken into the system, the quantity of earthy phosphates in the urine undergoes an increase. The small quantity of carbonate of lime taken into the system with the food, or set-free by the slow disintegration of the osseous tissue, is probably excreted in Man almost entirely in the form of phosphate, although of the much larger amount ingested by herbivorous animals, a considerable proportion is excreted in the urine in its original state. The Earthy Phosphates, although insoluble in water, are soluble in all acid liquids: and they are held in solution in Urine, like the urates, by the acid phosphate of soda. Their precipitation in an alkaline state of the urine is owing to the want of this solvent, not to an excess in their production; for, as Dr. Bence Jones has pointed-out, that excess of alkaline and earthy phosphates in the urine which constitutes the true 'phosphatic diathesis,' is generally coincident with a highly-acid state of the urine.—The only other inorganic saline constituent of the Urine, whose quantity gives it importance, is *Chloride of Sodium.* By far the larger proportion of this is doubtless derived directly from the food; but little being furnished by the disintegration of muscle, which will set-free potash rather than soda. The amount eliminated by the urine is consequently subject to great variation, it being the function of the Kidneys to remove whatever is superfluous, so as to prevent the blood from becoming overcharged with this substance. Of the chloride of sodium introduced as food, a part appears to undergo decomposition in the system, whereby hydrochloric acid is furnished to the gastric fluid, and soda to the bile; much of this acid, however, must reunite with its base in the alimentary canal, so that the chloride of sodium thus regenerated will be absorbed with the products of the digestive operation.—Although *Nitric Acid* can scarcely be regarded as a normal constituent of the Urine, yet the investigations of Dr. Bence Jones* appear to show that it is formed by a combustive process within the body, whenever ammoniacal salts are introduced into the system; its amount, however, being very small. He has also found that it is generated after the ingestion of small quantities of urea; a fact which affords some confirmation to the doctrine of Frerichs (§ 409), that urea may undergo decomposition into carbonate of ammonia, whilst still circulating in the current of blood. -The presence of *Oxalic Acid* in the urine (in combination with Lime) has been usually regarded as a pathological phenomenon, consequent upon an irregular performance of the retrograde metamorphosis of the tissues; but there can be no doubt that it may also result from the presence of soluble salts of oxalic acid in certain articles of vegetable food.†

415. The ordinary *acid* reaction of the Urine appears to be due, not to the presence of any free acid, but to the conversion of the *basic* phosphate of soda into the *acid* phosphate, by the subtraction of a part of the base, which occurs when uric, hippuric, lactic, or other free acids come into

* "Philosophical Transactions," 1851.—It is right to state, however, that this doctrine has been called in question by some eminent authorities, who deny the validity of the test for nitric acid employed by Dr. Bence Jones.

† See Dr. Golding Bird on "Urinary Deposits."

contact with the former substance. There is no adequate reason to believe, that, in the healthy state, there is ever any other cause than this; although in morbid urine, free organic acids are almost certainly present.* It has been shown by the researches of Dr. Bence Jones,† however, that the acid reaction is far from being constant in its degree, even when an ordinary mixed diet is steadily employed; for that it varies at different periods of the day, increasing and decreasing *inversely with the acidity of the stomach* (§ 98). Thus the acidity of the Urine decreases soon after taking food, whilst that of the Stomach is increasing; and attains its lowest limit from three to five hours after a meal, frequently giving place to an alkaline reaction. The acidity then gradually increases, whilst that of the stomach is decreasing; and attains its highest limit after a fast of some hours, when the stomach is quite empty, and its secretion returns. If no food be taken, the acidity does not decrease, but remains at nearly the same point for ten or twelve hours. When *animal* food was solely employed, the diminution of the acidity after a meal was more marked and continued longer, than when a mixed diet was eaten (apparently on account of the greater demand for acid in the stomach); and the acidity did not rise quite so high after fasting, as with a mixed diet. On the other hand, when the diet was purely *vegetable*, the diminution of the acidity of the urine was never such as to render it absolutely alkaline, although its acidity was reduced to the point of neutrality; and the increase of its acidity after fasting was sometimes very considerable, though by no means so marked as the decrease of alkalescence.—These diurnal variations in the acidity of the urine make it highly probable that corresponding variations occur in the alkalescence of the blood; such diurnal variations being produced by the quantity of acid separated from it, and poured into the stomach for the purpose of dissolving the food. The introduction of dilute sulphuric acid into the stomach, even in large doses, was not found to produce any decided change in the acidity of the urine; the only perceptible effect being a slight diminution of the decrease which takes place after taking food, and a slight augmentation of the increase after fasting. On the other hand, the use of liquor potassæ in large doses lessens the acidity of the urine, preventing it from rising after fasting to the height it would otherwise attain, and increasing its alkalescence after a meal; but it does not render the urine by any means constantly alkaline, nor does it hinder the variations produced by the state of the stomach from being very evident. Tartaric acid in large doses temporarily increases the acidity of the urine, causing it to rise considerably higher than usual after a fast, but not preventing that which is passed a few hours after food from becoming alkaline. Tartrate of potash in large doses, on the other hand, has a marked effect in rendering the urine alkalescent; still, it does not prevent the usual recurrence of the acidity some hours after a meal.

416. The Urine of Herbivorous animals is almost invariably *alkaline*, partly because their food contains a large quantity of alkaline and earthy bases, in combination with citric, tartaric, oxalic, and other acids, which are decomposed within the system; and partly because the amount of

* See Prof. Lehmann's "Physiological Chemistry," (Cavendish Society's Edition), vol. i. pp. 404–406.

† "Philos. Transact.," 1849.

sulphuric and phosphoric acids, generated as products of the oxidation of the elements of the tissues or of the surplus-food, is not sufficient to neutralize them. Such is the condition which occasions the alkalinity of Human Urine, when a portion of the acid which would otherwise show a predominance, is directed into another channel, and it is exaggerated in those states, in which, either from the irritating nature of the food, or from the irritable condition of the stomach, an undue quantity of acid is poured-out into that viscus; so that, its reaction being habitually acid, that of the urine becomes habitually alkaline. Such a state of the urine must be carefully distinguished, as Dr Bence Jones has pointed-out,* from that in which the alkalescence is due to the presence of *volatile*, and not to that of *fixed* alkali; the difference being easily recognizable by the influence of the liquid upon reddened litmus-paper, for the restoration of its blue colour is permanent in the latter case, but only transitory in the former. The alkalescence due to the presence of volatile alkali is due to the decomposition of urea, whilst the urine is yet within the bladder, through the agency of morbid secretions of that viscus, and it disappears when this organ returns to its healthy state. On the other hand, the alkalescence from fixed alkali proceeds from disordered action of the stomach, which is usually connected with disorder of the general system; and it persists until this can be remedied. In both forms of alkalescence, there is a precipitation of earthy phosphates; but in the alkalescence from fixed alkali, the precipitate usually consists almost entirely of phosphate of lime, whilst in that from volatile alkali, the amorphous sediment of phosphate of lime is mingled with prismatic crystals of the phosphate of ammonia and magnesia. These precipitates may be obtained from healthy urine, by adding to it a solution of potash or of ammonia; and the decomposition of such urine, which begins to take place very soon after it leaves the body, gives rise to the same precipitation, by the production of carbonate of ammonia at the expense of its urea.

417. A very important series of experiments has been performed by Prof. Lehmann, with a view to determine the influence of *diet* upon the constitution of the Urine. In the *first* set of these experiments, he adopted an ordinary *mixed* diet, but he took no more solid or liquid aliment, than was needed to appease hunger or thirst, and abstained from fermented drinks. Every two hours he took exercise in the open air, but he avoided immoderate exertion of every kind. The average result of the examination of the Urine passed under these circumstances, for fifteen days, is given in the first line of the subsequent table.—In a *second* set, Prof L. lived for twelve days on an exclusively *animal* diet, and for the last six of these, it consisted solely of eggs. He took 32 eggs daily; which contained 2420 grains of dry albumen, and 2431 grs. of fatty matters; or about 3532 grs. of carbon, and 465½ grs. of azote. The amount of Urea is shown, in the second line of the table, to have undergone a very large increase; and it contained more than five-sixths of the whole azote ingested.—In a *third* set, Dr. L. lived for twelve days on a *vegetable* diet; and its effect upon the solid matter of the Urine is shown in the third line of the table. -In a *fourth*, he lived for two days upon an *unazotized*

* "Medical Times," Dec. 13, 1851.

diet, consisting entirely of pure farinaceous and oleaginous substances; so that the azotized matter of the Urine must have been solely the result of the disintegration of the tissues. It is seen to undergo a very marked diminution, under this regimen; as is shown in the fourth line of the table. His health was so seriously affected, however, by this diet, that he was unable to continue it longer.

	Solid Matters.	*Urea.*	*Uric Acid.*	*Extractive Matters and Salts.*
I. Mixed diet .	1047·14 grs.	501·76 grs.	18·26 grs.	196·65 grs.
II. Animal diet .	1350·07 ,,	821·37 ,,	22·32 ,,	112·89 ,,
III. Vegetable diet	914·06 ,,	347·10 ,,	15·77 ,,	295·95 ,,
IV. Non-Azotized diet	643·53 ,,	237·90 ,,	11·34 ,,	254·48 ,,

The following inferences are drawn by Prof. Lehmann, from these experiments:—1. Animal articles of diet augment the *Solid matters* of the Urine. Vegetable substances, and still more such as are deprived of azote, on the contrary, diminish it.—2. Although Urea is a product of the decomposition of the organism, yet its proportions in the urine depend also on the food, for we find that a richly-azotized diet considerably augments its quantity. In the above experiments, the proportion of the Urea to the other solid matters was as 100 to 116 on a mixed diet; as 100 to 63 on an animal diet; as 100 to 156 on a vegetable diet; and as 100 to 170 on a non-azotized diet. 3. The quantity of *Uric acid* depends less on the nature of the diet, than on other circumstances; the differences observed in it being too slight to warrant our ascribing them solely to the former cause.—4. The Protein-compounds, and consequently the azote of the food, are absorbed in the intestinal canal; and what is not employed in the formation of the tissues, is thrown-off by the Kidneys in the form of Urea or Uric acid; these organs being the chief, if not the sole, channel through which the system frees itself of its excess of azote.—5. The urine contains quantities of *Sulphates* and *Phosphates* proportional to the azotized matters which have been absorbed, and the proportion of these salts is sensibly increased under the use of a large amount of those substances.—6. In the same circumstances, the *Extractive matters* diminish, while their quantity is increased by the use of Vegetable diet; a fact which proves the influence of vegetable aliment over the production of these matters in the urine.—7. The urine after the use of animal food has a strong acid reaction, but contains little or no lactic acid and no hippuric acid. Under a vegetable diet there is more lactic acid, but it is united to bases; and a large proportion of the free acid disappears.*

418. Thus, then, we have seen that the Kidneys serve as the special instruments for depurating the Blood of those *highly-azotized* compounds, which are formed in the system by the decomposition of the materials of the albuminous and gelatinous tissues, and also by that of the non-assimilated components of the food. We have seen also, that they serve for the removal of certain excrementitious compounds, of which *carbon* is a principal ingredient; and these, although normally present in but small amount, may undergo a marked increase in disease, especially when the liver is insufficiently performing its functions, or the respiratory process is obstructed. Further, we have been led to regard the Kidneys as the

* "Physiological Chemistry" (Cavendish Society's Ed.), vol. ii. pp. 450–452.

emunctory, not only for the superfluous water of the blood, but also for those saline compounds, which, having been introduced into the system, or generated within it, in larger amount than is compatible with the normal constitution of the blood, or than is required for the reparation of the solids of the body, or for the production of its fluid secretions, are only fitted for elimination (§ 216). On this point a very elaborate series of researches was made by Wohler,* who showed that of the soluble salts taken into the circulation, those are most readily excreted, which produce a determination of blood towards the kidneys, whereby an increased quantity of liquid is filtered-off through the outlet which they afford. This statement is to be extended from saline compounds, to such other soluble matters as are not eliminated by preference through other channels, or are present in too large an amount to find their way out thence with sufficient rapidity. Thus we have seen that when Sugar is injected into the blood in sufficient quantity, it appears in the urine (§ 132); and the same result may occur, either from the introduction of this substance in excessive amount by absorption from the alimentary canal, or from the undue production of it within the system (§ 402), especially if at the same time the process of Respiration, by which it is normally disposed-of as fast as it is formed, should be retarded or enfeebled.† The same may be said of Lactic acid, which is not, any more than Sugar, a normal constituent of the Urine; but which not unfrequently appears in this excretion, in consequence of its being generated in the system faster than it can be decomposed by oxidation and eliminated by the respiratory process. In like manner, too, the system makes an effort to free itself (so to speak) from various substances altogether foreign to it, which have been introduced into the circulating current by absorption, and which would be injurious if retained; the rate at which it does so, being in a great degree dependent upon the functional activity of the Kidneys (§§ 223, 224).

419. It is a most important fact, in a Dietetic and Therapeutic point of view, that the metamorphic process, of which the greater part of the constituents of the urine are the products, should be capable of retardation or of acceleration by the presence of other substances in the blood. The former appears to be the operation of *theine*, which is the active principle of Tea and Coffee; for, according to the recent observations of Dr. Bocker‡ upon the former, and of Dr. Julius Lehmann§ upon the latter, a very decided decrease shows itself in the amount of urea and of phosphoric acid excreted in the urine, when these beverages are employed, as

* "Muller's Elements of Physiology," translated by Baly, p. 589.

† It must be confessed that the rationale of the remarkable fact first discovered by M. Claude Bernard ("Gazette Médicale," Juin 2, 1849), that irritation of the floor of the fourth ventricle, by puncture or by a slight galvanic shock, causes the urine to become saccharine, whilst a more severe lesion checks the elimination of sugar, apparently by stopping its production,—has not yet been fully made out. Nevertheless, the statement in the text may probably be accepted as representing *a part* of the truth upon this curious subject. (See Reynoso in "Comptes Rendus," tom. xxxiii, xxxiv, Michéa, op. cit., tom. xxxiv; Dechambre in "Gazette Medicale," 1852, No. 14; Dr. L. Beale in "Brit. and For. Med. Chir. Rev.," vol. xi. p. 106; and Prof. Lehmann in his "Physiologischen Chemie," 2nd edit., band ii., pp. 217, 375.

‡ "Archiv des Vereins fur gemeinschaftlichen Arbeiten zur Forderung der Wissenschaftlichen Heilkunde," 1854.

§ "Annalen der Chem. und Pharm.," band lxxxvii.

compared with the amounts of the same substances when the general regimen was as nearly as possible identical in other respects, but plain water was substituted as a drink. The difference is much greater in the case of Coffee than in that of Tea, amounting generally to as much as one-fourth; thus:—

	Urea.	Phosphoric acid.	Common salt.
	grammes.	grammes.	grammes.
H. S., without coffee, voided	31·298	4·421	9·865
,, with coffee from $1\frac{1}{2}$ oz. of beans .	21·888	3·001	8·819
Difference	9·410	1·420	1·046

It appeared from other experiments, that neither caffeine nor the empyreumatic oil, separately administered, produce the same effect as coffee itself. Hence it appears that the use of Tea or Coffee, by retarding the 'waste' of the system, diminishes the demand for food, and makes a limited amount of it go further; and this conclusion seems fully borne out by experience.—The like results happen, according to Dr. Becker,* under the use of small quantities of Alcohol frequently repeated, as much as $13\frac{1}{2}$ grammes less urea being excreted daily, when a tea-spoonful of proof-spirit was taken seven or eight times a day, than when water alone was drank. It does not hence follow, however, that Alcohol can be used as advantageously for this purpose as Tea or Coffee; in fact, it may be doubted whether it is so much by diminishing the 'waste' of matter, as by interfering with the due elimination of its products, that Alcohol occasions a diminution in the weight of the urinary solids. For, as we have seen (§ 316 VI.), it interposes a marked obstruction to the due oxidation of the excrementitious matter, which has been received back into the blood for the purpose of elimination, and to the removal of the hydrocarbonaceous portion of it; and further, very cogent evidence is supplied by the experience of Zymotic diseases, that the very same cause produces an accumulation of fermentable azotized substances in the blood (§ 65).—It seems not unlikely that the almost instinctive craving for Tobacco among a large proportion of mankind, arises out of its possession of a power of retarding the metamorphosis of the tissues; since we find that men, when supplied with this article, can far better sustain being put upon a short allowance of food, than when destitute of it.

420. Of the substances that accelerate the metamorphosis of the tissues, and thus augment the solids of the urine, the Alkalies and their carbonates are those whose action is best known; these (with such of their salts as are formed by acids which are decomposed in the blood into the carbonic, such as the acetates, tartrates, and citrates), have a powerful solvent action on the albuminous compounds generally, and tend to break-up these compounds into simpler forms of combination. Hence it seems likely that their presence in the Blood in increased amount, will tend to hasten the retrograde metamorphosis of the tissues; their chemical force being exerted, not merely upon those which are already in a state of disintegration, but also upon those, which, being disposed to degenerate, cannot exercise that resisting power, which they possess when in a state of complete vital activity. The operation of Liquor Potassæ in health,

* Op. cit., 1853.

in acute rheumatism, and in chronic diseases, has been carefully studied by Dr. Parkes,* and he has given satisfactory evidence that it causes an increase in the solids of the urine generally, but especially in the urea and in the amount of the sulphuric and phosphoric acids, thus clearly showing that it hastens the metamorphosis of some of the albuminous structures of the body. The increase was more marked, as might be expected from what has been just stated, in the cases of chronic disease, than in ordinary health. The following comparative tables show the relative amounts before, during, and after, the employment of liquor potassæ, in (I.) a case of chronic Eczema, and (II.) a case of chronic Phthisis:

I	*Solids*	*Urea.*	*Sulphuric Acid*	*Phosphoric Acid*
Before Liq. Pot. . . .	660·1	371·5	29·2	11·6
During	689·6	454·5	33·5	15·4
After	527·2	372·8	29·0	10·9
II				
Before Liq. Pot.	608·2	368·8	18·6	9·9
During	781·7	408·8	20·9	14·5
After	643·9	271·5	16·9	9·7

A similar Table has been given by Dr. Golding Bird,† of the entire constituents of the secretion passed during 24 hours, before and after the administration of three drachms of acetate of potash:—

	Before Medicine	*After Medicine*
Quantity of Urine . .	fl ℥ xvi	fl ℥ xlvi.
Specific Gravity	1·025	1·017
Total Solids	416 grs.	782 grs.
Uric Acid	2·6 grs.	5·5
Urea	130·5 ,,	202·4
Other Organic Compounds .	189·3 ,,	295·5
Soluble Salts	72·0 ,,	248·4
Insoluble Salts	21·6 ,,	32·2

The increase (176·4 grains) in the quantity of 'soluble salts,' is to be chiefly set-down to the account of the medicine taken in; but the whole remainder of the augmentation seems fairly attributable to the increased metamorphosis. A certain degree of such increase is producible by the simple ingestion of a large amount of Water;‡ so that this is by no means so inoperative as it might at first sight appear, in cleansing and purifying (so to speak) the penetralia of the system.—It does not appear, however, that the excretion of the urinary solids is augmented by those 'diuretic' medicines, which cause a larger amount of liquid to be passed off through the Kidneys, merely by determining an increased flow of blood to them. On the contrary, it would seem as if, by producing congestion and irritation, they sometimes interfered with the normal process of secretion; so that the quantity of solid constituents is actually decreased, notwithstanding the large augmentation in the watery part of the urine. This very important fact has been demonstrated by Prof. Krahmer,§ who

* "Brit. and For. Med.-Chir. Review," vols. xi., xiii., xiv.

† See his "Lectures on the Influence of Researches in Organic Chemistry on Therapeutics," in "Medical Gazette," 1848, vol. xlii., p. 230.

‡ See Dr. Bockers, in "Zeitschrift der K. K. Gesellschaft der Aertze zu Wien," April, 1851.

§ "Heller's Archiv.," Dec. 1847.

gives the following as the result of his observations upon the amount excreted in 24 hours, after the administration of diuretics to persons in health:—

Medicine given.	*Total Solids in Urine*	*Organic Compounds.*	*Inorganic Compounds.*
None	2·40 oz.	1·28 oz.	1·12 oz.
Juniper	2·12 ,,	0·94 ,,	1·18 ,,
Venice Turpentine . .	1·94 ,,	1·11 ,,	0·82 ,,
Squill	2·25 ,,	1·04 ,,	1·21 ,,
Digitalis	2·45 ,,	1·28 ,,	1·17 ,,
Guaiacum	2·43 ,,	1·18 ,,	[illegible] ,,
Colchicum	2·32 ,,	1·36 ,,	0·96 ,,

Similar results have been obtained by Dr. Golding Bird.—It seems highly probable that the 'critical evacuations' of urine, as of sweat or fæcal matter, on which the older physicians were accustomed to lay great stress, are really charged with noxious substances, of which the blood is thus depurated; and that great benefit would frequently arise in practice from the use of the 'alterative diuretics,' as suggested by Dr. G. Bird, where (as in chronic rheumatism, gout, &c.,) there is reason to believe that a quantity of mal-assimilated matter exists in the system, of which it is important to get-rid. In many such cases, indeed, clinical observation had already established the benefit derivable from such medicines, without affording the rationale of it.

4.—*Of the Skin;—Cutaneous Transpiration.*

421. The Skin is the seat of various secretions,—as the Sebaceous, Ceruminous, and Odoriferous,—for each of which it is provided with special organs (PRINC. OF GEN. PHYS.); but these have reference to its own protection, or to some other *local* purpose, and the only one which can be regarded as truly *excrementitious*, is the Transpiration of aqueous fluid, holding certain matters in solution. The elimination of this fluid from the blood is effected by the *Sudoriparous* glandulæ (Fig. 74), which essentially consist of long convoluted tubes (*a*, *a*) rarely single, but usually multiplied by repeated dichotomous subdivision, and sometimes also giving off short cæcal processes before their termination. These are seated rather beneath the Corium, in the midst of the subcutaneous adipose tissue, than in the substance of the skin itself. All the tubuli of each gland unite so as to form but one duct; and this passes upwards through the Cutis and Cuticle, in a somewhat corkscrew-like manner (*c*), to open upon the surface of the latter (*d*), which it usually reaches obliquely, so that the outer layer of the Epidermis forms a sort of little valve, which is lifted by the secreted fluid as it issues-forth. These glandulæ are diffused in varying proportions over the entire surface of the body. According to Mr. Erasmus Wilson,* as many as 3528 of them exist in a square inch of surface on the palm of the hand; and since every tube, when straightened-out, is about a quarter of an inch in length, it follows that, in a square inch of skin from the palm of the hand, there exists a length of tube equal to 882 inches, or 73½ feet. The number of glandulæ in other parts of the Skin is sometimes greater, but

* "On the Management of the Skin," 3rd edit. p. 37

is generally less than this; and, according to Mr. Wilson, about 2800 may be taken as the average number of pores in each square inch throughout the body. Now the number of square inches of surface, in a man of ordinary stature, is about 2500; the total number of pores, therefore, may be about *seven millions*, and the length of the perspiratory tubing would thus be 1,570,000 inches, or 145,833 feet, or 48,611 yards, or nearly 28 miles.

Fig. 74.

Sudoriparous Gland from the palm of the hand magnified 40 diam.; a, a, contorted tubes, composing the gland, and uniting in two excretory ducts, b, b, which unite into one spiral canal that perforates the epidermis at c, and opens on its surface at d. the gland is imbedded in fat vesicles, which are seen at e, e.

422. Although a separation of fluid by this extensive glandular apparatus is continually taking-place, yet this fluid, being usually carried-off in the form of vapour as fast as it is separated, does not ordinarily accumulate so as to become sensible. If, however, from the increased amount of the secretion, or from the condition of the surrounding air, the whole fluid thus poured-out should not evaporate, the residue forms minute drops upon the surface of the skin. Thus the Sudoriparous excretion may take the form either of *sensible* or of *insensible* transpiration; the latter being constant, the former occasional.—It is difficult to obtain enough of this secretion for analysis, free from the sebaceous matters, epidermic scales, &c., which accumulate on the surface of the skin; and its character can only, therefore, be stated approximately. It usually shows an acid reaction, which seems due to the presence of acetic acid; and to this, or to lactic acid, we are probably to attribute the sour smell which it has, especially in some disordered states of the system. The proportion of solid matter contained in different specimens differs very greatly; thus, according to Anselmino, it varies between 5 and 12·5 parts in 1000; the recent observations of Favre* give 4·43 parts per 1000 as the proportion contained in nearly nine gallons which he had collected; whilst those of Schottin† raise it as high as 22·4 parts per 1000, of which, however, 12 parts consist of epithelium and insoluble matters. The greater part of it consists of organic matter, the larger proportion of which appears to be a protein-compound in a state of incipient

* "Archiv. Génér. de Méd.," 1853, 5ième Sér., tom ii., pp. 1-12.
† "Arch. fur physiol. Heilkunde," band ii. pp. 73-104.

decomposition; urea, however, has been detected in this product by Dr. Landerer;* and his observations are confirmed by Favre (loc. cit.), who considers that it is upon the presence of this or a similar substance that the readiness with which the fluid becomes alkaline depends. Schottin, however, failed in detecting urea in normal sweat; but he remarks that in *uræmia*, especially when occurring in cases of cholera, considerable quantities of this substance pass into the cutaneous transpiration, so as even to form a thin bluish pulverulent layer on the dead body. The remainder consists of saline compounds; of which the chlorides of potassium and sodium appear to be pretty constantly present; whilst muriate of ammonia, alkaline phosphates, free acetic and butyric acid, and acetate of soda, have also been said to occur in it. The presence of lactic acid is affirmed by Favre, and denied by Schottin; the former observer also affirms that he has discovered a new nitrogenous acid in this excretion, to which he has given the name of *hydrotic* or *sudoric acid*. The proportion of solid ingredients would probably be found larger in the true secretion of the Sudoriparous glands, if we had the means of collecting it separately; for of the whole fluid which passes off from the surface of the skin, only a portion can be properly said to be *secreted* by these glands, a large part, as in the case of the Kidneys, being apparently the product of simple *transudation* (§ 406). It will be this part which will undergo augmentation, when a special determination of blood to the skin is produced by external heat; and there is no more reason to think that an increase in the amount of *solid* matter thus excreted is induced by such agency, than that an increase in the solids of the urine can be determined by ordinary diuretics (§ 420). Hence the debilitating effects commonly assigned to profuse perspirations, must be attributed to some other causes; and these it does not seem very difficult to find. Thus, the great fatigue which is experienced as a consequence of muscular exertion in a heated atmosphere, may fairly be set-down to the diminished activity of the respiratory process at high temperatures (§ 316); and the 'colliquative sweating' of hectic fever is obviously not a cause, but a consequence, of the debilitated state of the general system.

423. The entire amount of fluid which is 'insensibly' lost from the Cutaneous and Pulmonary surfaces, is estimated by Seguin at 18 grains per minute; of which 11 grains pass-off by the skin, and 7 by the lungs. The maximum loss by Exhalation, cutaneous and pulmonary, during twenty four hours, (except under very peculiar circumstances,) is 5 lbs; the minimum $1\frac{3}{4}$ lb. It varies greatly, according to the condition of the atmosphere, and that of the body itself; and these variations, as we shall hereafter see (§ 444), have a most important share in the regulation of the temperature of the body. The whole amount of Cutaneous transpiration, 'sensible' and 'insensible,' is greatly increased by heat and dryness of the surrounding air; for the heat occasions the determination of an augmented amount of blood to the cutaneous vessels; and of the fluid which thus transudes, a large portion is carried-off in the state of vapour. The more the heated atmosphere is already charged with watery vapour, the smaller will be the proportion of the transuded fluid that will thus 'insensibly' pass away; and the more will accumulate as 'sensible' perspiration. Exact observations on this point, however, are much wanting.

* "Heller's Archiv.," band iv. p. 196.

which not merely the temperature, but the hygrometric state of the air should be precisely determined; the best hitherto recorded being those made by Dr. Southwood Smith* at the Phœnix Gas Works, in which the former element only was carefully noted. These observations were made upon eight of the workmen employed in 'drawing' and 'charging' the retorts and in making-up the fires, during which they are exposed to intense heat; the men were accurately weighed in their clothes, immediately before they began, and after they had finished their work; and in the interval between the first and second weighings, they were not allowed to partake of any solid or liquid *ingesta*, nor to part with urine or fæces.

Experiment I. Nov. 18, 1836. Day bright and clear. Temperature of the air in which the men worked, 60° Fahr. Barometer 29·25 in. to 29·4 in. Duration of labour, 45 minutes.—Average loss of weight, 3 lbs. 6 oz.; maximum, 4 lbs. 3 oz.; minimum, 2 lbs. 8 oz.

Experiment II. Nov. 25, 1836. Day foggy, with scarcely any wind. Temperature of the air, 39° Fahr. Barometer 29·8. Duration of labour, 75 minutes.—Average loss of weight, 2 lbs. 2 oz.; maximum, 2 lbs. 15 oz.; minimum, 14 oz.

Experiment III. June 3, 1837. Day exceedingly bright and clear, with little wind. Temperature of the air, 60°. Duration of labour, 60 minutes.—Average loss of weight, 2 lbs. 8 oz.; maximum, 3 lbs.; minimum, 2 lbs.

Experiment IV. On the same day, two other men worked in an unusually hot place for 70 minutes, the loss of weight of one of these was 4 lbs. 14 oz.; and of the other 5 lbs. 2 oz.

Although the individuals subjected to these experiments were not in all instances the same, yet there was enough of identity among them, to admit of the certain inference, that the amount of fluid lost must be influenced by the state of the individual system, as well as by that of the surrounding medium. Thus in the second experiment, Michael Griffiths lost 2 lbs. 6 oz., and Charles Cahell 2 lbs. 15 oz.; whilst in the third, Michael Griffiths lost 3 lbs., and Charles Cahell only 2 lbs. It is probable that the amount of liquid ingested not long previously, might have a considerable influence on the quantity lost by transpiration under such circumstances.

424. The Cutaneous excretion, as already pointed-out, is in great degree vicarious with the Urinary, in regard to the amount of fluid eliminated; the urine being more watery in proportion as the cutaneous exhalation is diminished in amount, and *vice versâ* (§ 406). But we are also to look at these two excretions as vicarious, in regard to the elimination of the products of the 'waste' of the system. The share which the Skin has in this office has probably been generally under-rated. There is reason to believe that at least 100 grains of azotized matter are excreted from it daily, and any cause which checks this excretion, must throw additional labour on the kidneys, and will be likely to produce disorder of their function.—The secreting action of the Skin is influenced by general conditions of the vascular and nervous systems; which are as yet ill understood. It is quite certain, however, that through the influence of the latter the secretion may be excited or sus-

* "Philosophy of Health," vol. ii. pp. 391-396.

pended; this is seen on the one hand in the state of syncope, and in the effects of depressing emotions, especially fear, and its more aggravated condition, terror; and on the other, in the dry condition of the skin during states of high nervous excitement. It is very probable that, in many forms of fever, the suppression of the perspiration is a cause, rather than an effect, of disordered vascular action; for there are several morbid conditions of large parts of the surface, in which the suppression of the transpiration appears to be one of the chief sources of danger, having a tendency to produce congestion and inflammation of internal organs. From the experiments of Dr. Fourcault, it appears that complete suppression of the perspiration in animals, by means of a varnish applied over the skin, gives rise to a state termed by him 'cutaneous asphyxia;' which is marked by imperfect arterialization of the blood, and considerable fall of temperature (§ 436); and which, as it produces death in the lower animals, would probably do the same in Man. A partial suppression by the same means gives rise to febrile symptoms, and to albuminuria.*—There can be no doubt whatever, that imperfect action of the Cutaneous glandulæ, consequent upon inactive habits of life and want of ablution, is a very frequent source of disorder of the general system; occasioning the accumulation of that decomposing organic matter in the blood, which it is the special office of these glandulæ to eliminate. Hence the due maintenance of health requires that this excretion should be promoted by the use of the natural and appropriate means just referred-to; and this is the more necessary, when from any cause the function of the kidneys is imperfectly performed. There are many diseased states, moreover, in which there appears to be a special determination of the *materies morbi* to the Skin; and in which, therefore, the use of means that promote the cutaneous excretion constitutes the most efficient method of eliminating it from the blood.†

CHAPTER X.

EVOLUTION OF HEAT, LIGHT, AND ELECTRICITY.

1.—*General Considerations.*

425. The series of Nutritive operations which has now been passed in review, has been shown to consist in the continual appropriation, by the Animal organism, of certain 'organic compounds' or 'alimentary materials,' which have been generated for its use by Plants; and in the constant restoration of their elements to the Inorganic world, either in the

* See his important Treatise, "Causes Générales des Maladies Chroniques," &c., 1844; and "Brit. and For. Med. Rev.," vol. xx. pp. 106, 108.

† The practical value of active diaphoresis in many febrile diseases, is well understood by the native practitioners among the Negroes of the Guinea Coast, who according to Dr. Daniell ("Medical Topography and Native Diseases of the Gulf of Guinea," pp. 119, 20) make use of it most successfully in the treatment of adynamic remittent fevers. Dr. Daniell states that having himself had abundant experience of its efficacy, he has no doubt of its superiority in these cases to the ordinary practice of venesection, saline purgatives, large doses of calomel, &c. And he has repeatedly stated that one great secret of preserving health in tropical climates, lies in due attention to the cutaneous functions.

very same forms of combination in which they originally existed there, or as products of incipient decay, by whose further decomposition those simple binary compounds will be reproduced. And thus, so far as the material components of the Organic Creation are concerned, the agency of Vegetable life is concerned in withdrawing them from the Mineral world, and that of Animal life in returning them to it, after they have served their purpose in the living structure. But if we examine into the source of those active powers or 'forces,' on whose operation every change, no less in the organized body, than in what is commonly designated as 'inert' matter, is dependent, we shall find that they are all traceable to the solar radiations. It is by the action of the Light and Heat of the Sun upon the Vegetable germ, that it is enabled to exercise its wonderful transforming capacity, whereby it extracts carbon, hydrogen, nitrogen, and oxygen, from the carbonic acid, water, and ammonia furnished by the atmosphere or the soil; and that it converts these into the albuminous, saccharine, and oleaginous compounds, which are the destined food of Animals. And it is under the influence of Heat chiefly derived from the same source, that the greater number of tribes of Animals are enabled to apply these compounds to the purposes of organization, and that, through the peculiar instruments thus constructed, those various kinds of *Vital Force* are evolved, whose operations are so different from any which we witness in the Inorganic world. Accordingly we observe that the 'rate of life' in this larger proportion of the Animal kingdom, is regulated, as in Plants, by the amount of Heat supplied to the organism from external sources; and that, when the external temperature is reduced below a certain point, there is an entire cessation of all vital activity.* But there are certain tribes, especially Birds and Mammals, which possess the power of generating *Heat* within themselves, to such a degree as to render the rate of their vital processes almost entirely independent of external influences; and there is probably no one species that can exercise this power more effectually, and through a greater range of external conditions, than Man is able to do. Of this we shall presently have evidence.—The evolution of *Light*, again, is by no means an unusual phenomenon among the lower tribes of Animals; but where it does occur, it usually appears to have some special purpose, as is obvious enough in the case of the glow-worm and other luminous Insects. But the luminosity which is occasionally exhibited in Man (§ 445), must be regarded as an altogether abnormal phenomenon, whose physiological interest arises out of the peculiarity of the circumstances under which it presents itself. Of the degree in which *Electricity* is generated in the living body, we know comparatively little. There is strong evidence that a disturbance of Electric polarity must take place in every action of Organic as well as of Inorganic Chemistry; and thus that every molecular change in the Animal as well as in the Vegetable organism must involve an alteration in its electric condition. But it would seem that in the Animal body generally, these alterations are made to balance each other so exactly, that no considerable disturbance of the electric equilibrium ordinarily takes place in the organism as a whole; and it is only in certain peculiar cases (as in the Electric Fishes) that a provision exists for the generation of Electricity in considerable amount and intensity, with a view to some special purpose. In

* See "Principles of General Physiology."

the Human subject, however, an extraordinary production of free Electricity, as of Light, occasionally presents itself, and this, taken in connection with other evidence, would seem rather to indicate a departure from the *balance* usually maintained between the opposite electrical changes continually taking place, than to be due to the introduction of any extraordinary sources of electric disturbance (§ 446).

2. *Evolution of Heat.*

426. All the vital actions of the body of Man, as of that of 'warm-blooded' animals generally, require an elevated temperature as a condition of their performance; and the high degree of constancy and regularity which is observable in these actions, appears to depend in great degree upon the provision which the organism contains within itself, for the maintenance of that temperature at a fixed standard. This constancy and regularity are most remarkably exhibited in the various *periodical* changes to which the body is subject both in health and in disease, the uniformity of whose recurrence is due to a corresponding uniformity in the rate of vital action taking place in the interval. Thus, as will be shown hereafter, the period of parturition is in great degree determined by the maturation of the fœtal structures; and the uniformity of the time which this requires (like the corresponding uniformity in the period of development in the embryo-bird) may be fairly attributed to the regularity of the supply of Heat, which is the power that especially determines the formative operations. For the periods of all similar phenomena in 'cold-blooded' animals, which have no power of maintaining an independent temperature, exhibit no such uniformity; being entirely dependent (as in Plants) upon the degree of *external* warmth to which their bodies are subjected. We shall now inquire, in the first place, into the amount of Heat thus generated by Man; and then into the sources of its production.

427. Our present knowledge of the ordinary Temperature of the Human body under different circumstances, is chiefly due to the investigations of Dr J. Davy.*—The first series of his observations included 114 individuals of both sexes, of different ages, and among various races in different latitudes, and under various temperatures; the external temperature, however, was in no instance very low, and the variations were by no means extreme. The mean of the ages of all the individuals was 27 years. The following is a general statement of the results, the temperature of the body having been ascertained by a thermometer placed under the tongue :—

Temperature of the air	60°	Average temperature of the body	98·28
" "	69°	" " "	98·[illegible]
" "	78°	" " "	98·[illegible]
" "	79·5°	" " "	99·21
" "	80°	" " "	99·[illegible]
" "	82°	" " "	99·[illegible]
Mean of all the experiments	74°	Mean of all the experiments	100
Highest temperature of air	82°	Highest temperature of body	102°
Lowest temperature of air	60°	Lowest temperature of body	96·5°

* See Dr. Davy's successive Memoirs in the "Philosophical Transactions," for 18[illegible] (published in his "Anatomical and Physiological Researches") 1844, 1845, and [illegible]

From this we see that the variations noted by Dr. Davy, which were evidently in part the consequence of variations in external temperature, but which were also partly attributable to individual peculiarities, amounted to 5½ degrees; the lower extreme might be found to undergo still further depression, if the inquiries were carried-on in very cold climates.—Dr. Davy's subsequent inquiries have been directed to the determination of the various influences which tend to produce a departure from the average, and it will be advantageous to present his results in a systematized form, in combination with those of other observers. The most important of these variations seem to be those dependent upon Age, Period of the day, Exercise or Repose, Ingestion of Food or Drink, and External Temperature.

I. The temperature of *Infants*, according to the observations of Dr. Davy, M. Roger,* and of Dr. G. C. Holland,† is somewhat higher than that of adults,‡ provided that they are placed in conditions favourable to its sustenance; but, as will be shown hereafter, infants and young children are very inferior to adults in their power of resisting the depressing influence of external cold (§§ 442, 443). Their temperature, when examined immediately after birth by a thermometer in the axilla, is nearly 100°, but it quickly falls to about 95·5°, and gradually rises in the course of the next twenty-four hours to about 97·7° in weakly subjects, and to 99·5° in strong infants. Between four months and six years of age, M. Roger found the average temperature to be 98·9°; and between six and fourteen years of age, 99·16°. The temperature of *aged* persons, from the observations of Dr. J. Davy, does not seem to be below that of persons in the vigour of life, provided that there be no external depressing influences; but they seem, like infants and young children, to have less power of resisting external cold, the temperature of their bodies being more easily and considerably reduced by it than is that of adults; and hence probably it has happened, that popular opinion assigns to them an habitually inferior temperature.

II. A slight *diurnal* variation in the temperature of the body appears usually to take place, quite irrespectively of external heat or cold, but this does not seem to be very constant either in its period or its degree, and is seldom very considerable. Thus Dr. Davy found from a long series of observations carried-on upon himself whilst in England, that the body was warmest in the morning, and coldest at night; whilst the reverse was the case in Barbadoes. The following table gives his average results:—

	Mean temperature under the tongue			*Temperature of Room*		
England	7–8 A.M.	2–4 P.M.	12 P.M.	7–8 A.M.	2–4 P.M.	12 P.M.
	98·74°	98·52	97·92°	50·9°	54·7°	62°
Barbadoes	6–7 A.M.	12–2 P.M.	9–11 P.M.	6–7 A.M.	12–2 P.M.	9–11 P.M.
	98·07	98·9°	99°	76·7°	83·6°	79°

* "Archiv. Gén. de Méd.," 1844. † "Inquiry into the Laws of Life," 1829.

‡ Dr. W. F. Edwards ("On the Influence of Physical Agents on Life," p. 115) gives as the result of his observations, which were only ten in number, that the temperature of infants is lower than that stated above; but it is obvious that these observations were made during the period of depression which occurs in the first few days, whilst the respiratory function is becoming established.

From the observations of M. Chossat on Birds, in which the diurnal variation amounts to 1½° Fahr., it seems that the maximum pretty constantly occurs at noon, and the minimum near midnight; and this corresponds well with what has already been pointed out, with regard to the relative activity of respiration at different periods of the twenty-four hours (§ 316 ix). Probably there is a less capacity for generating heat during the night; so that, if the body be insufficiently protected by clothing or be exposed to a low degree of external temperature, its own temperature will be more readily lowered: and thus the minimum of the whole day may come to present itself at this part of it, in a temperate climate; whilst in a tropical climate, the light bed-covering and free circulation of air usual in the sleeping-room, together with the reducing influence of repose, would tend to render the early-morning temperature the lowest.

iii. That an increase in the heat of the body is produced by *exercise*, and that repose tends to its reduction, is a matter of familiar experience; yet the observations of Dr. Davy show that there is scarcely any perceptible difference in the heat of the deep-seated parts, the augmentation and depression being confined to the extremities. Thus, on one occasion recorded by him, the temperature of the air of the room before walking being 60°, that of the feet (shown by a thermometer placed between the toes) being only 66°, that of the thermometer under the tongue being [illegible], and that of the urine being 100°, —the temperature after a walk in the open air at 40°, the exercise having diffused a feeling of gentle warmth through the body, was 96·5° in the feet, 97° in the hands, 98° under the tongue, and 101° in the urine. So, on another occasion, the temperature having been 66° in the room, 75° in the feet, 81° in the hands, 98° under the tongue, and 100° in the urine,—after a walk in air at [illegible] the temperature was 99° in the feet, 98° in the hands, 98° under the tongue, and 101·5° in the urine.

iv. The influence of *ingestion of food* upon the temperature of the body has not yet been duly investigated. Common experience leads to the conclusion, that after a meal, as after exercise, there is a greater warmth in the extremities; but Dr. Davy's observations show that in his own person, whilst in England, there was usually an appreciable depression immediately after dinner, though in Barbadoes the effect of a moderate meal was to produce an elevation. In both cases, however, Dr D. observed that the ingestion of *wine* has a positively-depressing influence on the temperature of the body, which increases with the quantity taken; and it may have been the constant employment of wine with his dinner, which was the real cause of the depression observed in England.*

* This difference in effect noted by Dr. Davy, between a moderate quantity of wine taken with dinner in England and in Barbadoes, seems readily explicable by the fact that the presence of Alcohol in the blood diminishes for a time the energy of the proper combustive process (§ 316 vii). For when the temperature of the atmosphere is considerably below that of the body, this retardation of the combustive process occasioned by the wine will allow the heat of the body to be lowered by it, notwithstanding the tendency to increased activity of the circulation and respiration which the meal alone would exert. In a warm climate, on the other hand, the cooling influence of the external air would not be sufficient to produce this reduction in the temperature of the body, notwithstanding the retarding influence of the wine upon the combustive process.

v. The influence of *external temperature* is sufficiently apparent in the observations already cited; for although external cold may act in a different degree on different individuals, according to their respective ages, powers of resistance, &c., yet there is ample proof that on the whole a continued exposure to it reduces the temperature of the body somewhat below its ordinary standard, whilst continued exposure to heat occasions a slight elevation in the temperature of the body. The influence of cold is, of course, most powerfully exerted when the body is at rest, and under such circumstances Dr. Davy found the temperature of his own body to be reduced, on an average of four observations, to 96·7°, the average temperature of the surrounding air having been 37°. On comparing the bodily temperature of different individuals working in rooms of various temperatures in the same factory, Dr. Davy found the tongue-thermometer rise to 100° in one man, and to 100·5° in another who had been working for some hours in a room at 92°; whilst it was 99° in a young woman who worked in a room at 73°, and only 97·5° in another who worked in a temperature of 60°.—The effects of seasonal change are less marked in Man, than they are in the lower animals, which are more exposed to extremes of temperature, but it seems principally exerted in modifying the heat-producing power. For it has been shown by Dr. W. F. Edwards (Op. cit.), that warm-blooded animals are more speedily killed by extreme cold in summer than in winter; and it seems probable, therefore, that we are partly to attribute the peculiar chilling influence of a cold day in summer, and the oppressiveness of a warm day in winter, to the seasonal change in the body itself; although the effect is doubtless referable in part to the effect of contrast upon our own feelings.

428. The usual Temperature of the body occasionally undergoes considerable alteration in *disease*; and this in the way either of increase or of diminution. Thus in maladies which involve an acceleration of pulse and a quickening of the respiration, the temperature is generally higher than usual, even though a large portion of the lung may be unfit for its function. This is often remarkably seen in the last stages of phthisis, when the inspirations are extremely rapid, and the pulse so quick as scarcely to admit of being counted; the skin, in such cases, often becomes almost painfully hot. On the other hand, in diseases of the contrary character, such as 'morbus cæruleus,' asthma, and cholera, the temperature of the body falls; a reduction to 78° having been noticed in the former maladies, and to 67° in the latter. The range observed by M. Andral in diseases which less affected the calorifying function, was from 95° to 107·6°, and by M. Roger (loc. cit.), in diseases of children, from 74·3 to 108·5. Prof. Dunglison* speaks of having seen the thermometer at 106° in scarlatina and typhus; and Dr. Francis Home,† found it to stand at 104° in two individuals in the cold stage of an intermittent, whilst it afterwards fell to 101°, and subsequently to 99°, during the sweating stage. Dr. Edwards mentions a case of tetanus, in which the temperature of the body rose to 110¾°. The following observations have been made on this subject by M. Donné:‡ in a case of puerperal

* "Human Physiology," 7th edit., vol. ii. p. 225.
† "Medical Facts and Experiments," London, 1759.
‡ "Archiv. Gen. de Med.," Oct. 1835, and "Brit. and For. Med. Rev.," vol. ii. p. 248.

fever, the pulse being 168, and the respirations 48 per minute, the temperature was 104°; in a case of hypertrophy of the heart, the pulse being 150 and the respirations 34, the temperature was 103°; in a case of typhoid fever, the pulse being 136, and the respirations 50, the temperature was 104°; and in a case of phthisis, the pulse being 140, and the respirations 62, the temperature was 102°; on the other hand, in a case of jaundice, in which the pulse was but 52, the temperature was only 96·40°, but the same temperature was observed in a case of diabetes in which the pulse was 84. These limited observations, whilst they clearly indicate that a *general* relation exists between the temperature of the body and the rapidity of the pulse, also show that this relation is by no means invariable, but that it is liable to be affected by several causes, of which our knowledge is as yet very slight.—It is not a little remarkable that the temperature of the body should sometimes *rise* considerably *after death*, and this not merely in such diseases as Cholera, in which it has undergone an extreme depression during the latter part of life, but even in the case of febrile disorders, in which the temperature during life has been above the usual standard. This has been ascertained by Dr Bennet Dowler* of New Orleans, on the bodies of those yellow fever subjects which have already been referred to as exhibiting a remarkable degree of *molecular* life after *somatic* death (§ 269). In one case, for example, the highest temperature during life was in the axilla, 104°; ten minutes after death, it had risen to 109° in the axilla; fifteen minutes afterwards, it was 113° in an incision in the thigh; in twenty minutes, the liver gave 112°; in one hour and forty minutes, the heart gave 109°, and the thigh in the former incision 109°; and in three hours after the removal of all the viscera, a new incision in the thigh gave 110°. It is curious that the maximum heat observed after death should have been in the thigh, and the minimum in the brain; as is shown in the following table of the highest amount of temperature noted in eight different regions in five subjects:—

	Thigh	*Epigastrium*	*Axilla*	*Chest*	*Heart*	*Brain*	*Rectum*	*Liver*
	113°	111	109°	107°	109°	102°	111°	[illegible]
	109°	110°	109°	106·5°	106°	101°	[illegible]	[illegible]
	109	109°	108°	106°	105°	101°	[illegible]	[illegible]
	109°	109°	108°	106°	104°	100°	107°	[illegible]
	108°	109°	107°	105°	104°	99°	[illegible]	[illegible]
Mean	109·6°	109·6°	108·2°	106·1°	105·6°	100·6°	108°	[illegible]

429. Although there appears to be, for all kinds of animals, a distinct limit to the variations of bodily temperature, under which their vital operations can be carried on, this limitation does not prevent certain species from existing in the midst of great diversities of external conditions; since they have within themselves the power of compensating for these, in a very extraordinary degree. This power seems to exist in Man to a higher amount than in most other animals; since he can not only support, but enjoy life, under extremes of which either would be fatal to many. In many parts of the tropical zone, the thermometer rises every

* "Western Journal of Medicine and Surgery," June and Oct., 1844; cited in "Philadelphia Medical Examiner," June, 1845, and in Prof. Dunglison's "Human Physiology," 7th edit., vol. ii. p. 718.

day, through a large portion of the year, to 110°; and in British India it is said to be seen occasionally at 130°. On the other hand, the degree of cold frequently sustained by Arctic voyagers, and quite endurable under proper precautions, appears much more astonishing; by Captain Parry, the thermometer has been seen as low as —55°, or 87° below the freezing point; by Captain Franklin at —58°, or 90° below the freezing point; and by Captain Back at —70°, or 102° below the freezing point. In both cases, the effect of the atmospheric temperature on the body is greatly influenced by the condition of the air as to motion or rest: thus, every one has heard of the almost unbearable oppressiveness of the 'sirocco' or hot wind of Sicily and Italy, the actual temperature of which is not higher than has often been experienced without any great discomfort, when the air is calm; and, on the other side, it may be mentioned that, in the experience of many Arctic voyagers, a temperature of —50° may be sustained, when the air is perfectly still, with less inconvenience than is caused by air in motion at a temperature fifty degrees higher.* This is quite conformable to what might be anticipated on physical principles.

430. Again, the degree of *moisture* contained in a heated atmosphere, makes a great difference in the degree of elevation of temperature, which may be sustained without inconvenience. Many instances are on record, of a heat of from 250° to 280° being endured in *dry* air for a considerable length of time, even by persons unaccustomed to a particularly high temperature; and persons whose occupations are such as to require it, can sustain a much higher degree of heat, though not perhaps for any long period. The workmen of the late Sir F. Chantrey were accustomed to enter a furnace in which his moulds were dried, whilst the floor was red-hot, and a thermometer in the air stood at 350°; and Chabert the "Fire-king," was in the habit of entering an oven whose temperature was from 400° to 600°.† It is possible that these feats might be easily matched by many workmen who are habitually exposed to high temperatures; such as those employed in Iron foundries, Glass-houses, and Gas-works. In all these instances, the dryness of the air facilitates the rapid vaporization of the fluid, whose secretion by the Cutaneous glandulæ is promoted by heat applied to the surface; and the large amount of caloric which is consumed in this change, is for the

* The Author has been informed by Sir John Richardson, that in his last Arctic Expedition, whilst at winter quarters, he was accustomed to go from his sitting room to the magnetic observatory at a short distance (about an ordinary street's breadth), without feeling it necessary even to put on a great coat; although the temperature of the former was about 50°, and that of the air through which he had to pass to the latter was —50°, the difference being 100°. This immunity from chilling influence was chiefly attributable to the *dryness* and *stillness* of the atmosphere; but it is worthy of note that Sir J. R. and the whole of his party on this expedition, abstained entirely from alcoholic liquors; and the Author has received his personal assurance, that his experience on this occasion fully bore out his previous conviction, that continued severe cold is *much better* borne without recourse to these liquors, than under the employment of them.

† The wonderful feats performed by many individuals from time to time,—of dipping the hand into melted lead, laying hold of a red hot iron, &c.,—have been recently shown by M. de Boutigny to be explicable upon very simple principles. For in all such cases, a thin film of aqueous fluid in the 'spherical state' intervenes between the skin and the heated surface; and a hand which is naturally damp, or which has been slightly moistened, may be safely passed into the stream of *molten iron* as it flows from the furnace; as was demonstrated by M. de Boutigny at the meeting of the British Association at Ipswich in 1851.

most part withdrawn from the body, the temperature of which is thus kept-down.

431. Exposure to a very elevated temperature, however, if continued for a sufficient length of time, does produce a certain elevation of that of the body, as might be expected from the statements already made in regard to the variation in the heat of the body with changes in atmospheric temperature (§ 427). In the experiments of MM. Berger and Delaroche,* it was found that, after the body had been exposed to air of 120° during 17 minutes, a thermometer placed in the mouth rose to [illegible] 7° above the ordinary temperature; it may be remarked, however, that as the body was immersed in a close box, from which the head projected, (in order to avoid the direct influence of the heated air on the temperature of the mouth), the air had probably become charged with the vapour exhaled from the surface, and had therefore somewhat of the effects of a moist atmosphere. At any rate, the temperature of the body does not appear to rise, under any circumstances, to a degree very much greater than this. In one of the experiments of Drs. Fordyce and Blagden,† the temperature of a Dog, that had been shut-up for half-an-hour in a chamber of which the temperature was between 220° and [illegible], was found to have risen from 101° to about 108°. MM. Delaroche and Berger tried several experiments on different species of animals, in order to ascertain the highest temperature to which the body could be raised without the destruction of life, by inclosing them in air heated from 122° to 201°, until they died: the result was very uniform, the temperature of the body at the end of the experiment only varying in the different species between 11° and 13° above their natural standard: whence it may be inferred, that an elevation to this degree must be fatal. This elevation would be attained comparatively soon in a *moist* atmosphere; partly because of the greater conducting power of the medium, but principally on account of the check which is put upon the vaporization of the fluid secreted by the skin. Even here, however, custom and acquired constitution have a very striking influence; for whilst the inhabitants of this country are unable to sustain, during more than [illegible] or 12 minutes, immersion in a vapour-bath of the temperature of [illegible] or 120°, the Finnish peasantry remain for half an hour or more in a vapour-bath whose temperature finally rises even to 158° or 167°. Accurate experiments are yet wanting, to determine the influence of humidity on the effects of *cold* air. From experiments on young [illegible] incapable of maintaining their own temperature, of which some were placed in cold dry air, and others in cold air charged with moisture, it was found by Dr. Edwards that the loss of heat was in both instances the same; the effect of the evaporation from the surface in the former case, being counterbalanced in the latter by the depressing influence of the cold moisture. This influence, the existence of which is a matter of ordinary experience, is probably exerted directly upon the Nervous system.

432. Having thus considered the general facts which indicate the faculty possessed by the living system, in Man and the higher Animals

* "Experiences sur les Effets qu'une forte Chaleur produit sur l'Economie." Paris 1806; and "Journal de Physique," tomes lxiii., lxxi., et lxxvii.

† "Philosophical Transactions," 1775.

of keeping-up its temperature to an elevated standard, and of preventing it from being raised much beyond it by any degree of external heat, we have next to inquire to what this faculty is due.*—It may be stated as a general fact, that every change in the condition of the organic components of the body, in which their elements enter into new combinations with Oxygen, *must* be a source of the development of Heat. And as we have seen that a considerable part of the carbonic acid and water which are exhaled in Respiration, is formed within the body by the metamorphosis of its own tissues, and that this metamorphosis is promoted by the active exercise of the nervo-muscular apparatus, it follows that in animals whose habits of life are peculiarly active, whilst the temperature of the surrounding medium is sufficiently high to prevent its exerting any considerable cooling influence over them, the combustive process thus maintained may be adequate for the maintenance of the temperature of the body at its normal standard. This seems to be the case with the great Carnivorous quadrupeds of warm climates, and with certain races of Men who lead a life of incessant activity like theirs. But whenever the cooling influence of the atmosphere is greater, or the retrograde metamorphosis of tissue takes place with less activity, some further supply of heat-producing material is required; and this is derived either directly from the food, or from a store previously laid up in the body. Although the albuminous and gelatinous components of the food may be made, by decomposition within the body, to yield saccharine and oleaginous compounds which serve as an immediate *pabulum* to the combustive process (§ 402), yet this metamorphosis involves a great waste of valuable nutritive material, and the needed supply is much more advantageously derived at once from those farinaceous or oleaginous substances, which are furnished in abundance by the Vegetable kingdom, the latter also by the Animal (§ 54). No reasonable doubt can any longer be entertained, that the production of Heat by the combustive process is the purpose to which these substances are destined to be subservient in the bodies of Herbivorous animals and of Man; and the results of experience in regard to their relative heat-producing powers, are in precise accordance with the indications afforded by their chemical composition.

433. Our knowledge of the dependence of all the vital processes in warm-blooded animals upon the Heat of their bodies, and of the dependence of their calorifying power upon the due supply of material for the combustive process, has received some remarkable additions from the experiments of M. Chossat upon Starvation.† He found that Birds, when totally deprived of food and drink, suffered a progressive, though slight, daily diminution of temperature. This diminution was not so much shown by a fall of their maximum heat, as by an increase in the diurnal variation, which he ascertained to occur even in the normal state

* It was affirmed by Dr. Granville ("Phil. Trans.," 1825) that the temperature of the uterus during parturition sometimes rises as high as 120°. In some observations made at the Philadelphia Hospital, however, at the desire of Prof. Dunglison, the temperature of the uterus was not found to be much above that of the vagina; the former being, in three cases, 100°, 102°, and 106°, whilst the latter was 100°, 100°, and 105°. (Prof. Dunglison's "Human Physiology," 7th edit., vol. ii. p. 226.)

† "Recherches Expérimentales sur l'Inanition," Paris, 1843; an analysis of this work will be found in the "Brit. and For. Med. Rev.," April, 1844.

(§ 427 II). The average variation in the *inanitiated* state, was about 6° (instead of $1\frac{1}{2}$°), gradually increasing as the animal became weaker; moreover, the gradual rise of temperature, which should have taken place between midnight and noon, was retarded; whilst the fall subsequent to noon commenced much earlier than in the healthy state; so that the *average* of the whole day was lowered by about $4\frac{1}{2}$°, between the *first* and the *penultimate* days of this condition. On the *last* day, the production of heat diminished very rapidly, and the thermometer fell from hour to hour, until death supervened; the whole loss on that day being about 25° Fahr., making the *total* depression about $29\frac{1}{2}$°. This depression appears, from the considerations to be presently stated, to be the *immediate* cause of Death.—On examining the amount of loss sustained by the different organs of the body, it was found that 93 per cent. of the *Fat* had disappeared; being all, in fact, which *could* be removed; whilst the nervous centres scarcely exhibited any diminution in weight (§ 70). From the constant coincidence between the entire consumption of the fat, and the depression of temperature,—joined to the fact that the duration of life under the inanitiating process evidently varied (other things being equal) with the amount of fat previously accumulated in the body,—the inference seems irresistible, that the calorifying process depended chiefly, if not entirely, on the materials supplied by this substance. Whenever, therefore, the store of combustible matter in the system was exhausted, the inanitiated animals died, by the cooling of their bodies consequent upon the loss of calorifying power.

434. That this is the real explanation of the fact, was shown by the results of a series of very remarkable experiments performed by M. Chossat, with the purpose of testing the correctness of this view. When inanitiated animals, whose death seemed impending, (death having actually taken place in several instances, whilst the preliminary processes of weighing, the application of the thermometer, &c., were being performed) were subjected to artificial heat, they were almost uniformly restored, from a state of insensibility and want of muscular power, to a condition of comparative activity; their temperature rose, their muscular power returned, they flew about the room, and took food when it was presented to them; and if the artificial assistance was sufficiently prolonged, and they were not again subjected to the starving process, most of them recovered. If they were left to themselves too early, however, the digestive process was not performed, and they ultimately died. Up to the time when they began to take food, their weight continued to diminish; the secretions being renewed, under the influence of artificial heat, sometimes to a considerable amount. It was not until digestion had actually taken place (which, owing to the weakened functional power, was commonly many hours subsequently to the ingestion of the food), that the animal regained any power of generating heat; so that, if the external source of heat was withdrawn, the body at once cooled; and it was not until the quantity of food actually *digested* was sufficient to support the wants of the body, that its independent power of calorification returned. It is to be remembered that, in such cases, the resources of the body are on the point of being completely exhausted, when the attempt at re-animation is made; consequently it has nothing whatever to fall-back upon, and the leaving it to itself *at any time* until fresh resources have been provided for it, is

consequently as certain a cause of death, as it would have been in the first instance.

435. It can scarcely be questioned, from the similarity of the phenomena, that Inanitiation, with its consequent depression of temperature, is the immediate cause of death in various Diseases of Exhaustion: and it seems probable that there are many cases, in which the depressing cause is of a temporary nature, and in which a judicious and timely application of artificial heat might prolong life until it has passed off, just as artificial respiration is serviceable in cases of narcotic poisoning (§ 224). It is especially, perhaps, in those forms of Fever, in which no decided lesion can be discovered after death, that this view has the strongest claim to reception; and the beneficial result of the administration of Alcohol in such conditions, and the large amount in which it may be given with impunity, may probably be accounted-for on this principle. That it acts as a specific stimulus to the Nervous system, cannot be doubted from its effects on the healthy body; but that it serves as a *fuel* to keep-up the calorifying process, appears equally certain. Its great efficacy in such cases seems to depend upon the readiness with which it will be taken into the circulation, by a simple act of endosmotic imbibition, when the special Absorbent process, dependent upon the peculiar powers of the cells of the villi (§ 121), is in abeyance. There is no other combustible fluid, whose miscibility and whose density, relatively to that of the Blood, will permit of its rapid absorption by the simple physical process adverted-to.*

436. That the oxidation of certain components of the food or of the tissues is the fundamental source of Animal Heat, is further indicated by the close conformity which we everywhere find, between the activity of the Respiratory process and the amount of Heat which is generated; and this not merely when we compare different tribes of animals with each other, but also when we compare the amount of oxygen absorbed and of carbonic acid exhaled by the same individuals under different degrees of external temperature (§ 316 i). For we find that the system possesses within itself a regulating power, by which the combustive process is augmented in activity when the cooling influence of the surrounding medium is considerable, so that this influence is resisted; whilst the internal fire (so to speak) is slackened, whenever the temperature of the outer air rises so much, as to render the same generation of heat no longer requisite. The appetite for food, and especially for those particular forms of it which best afford the combustive pabulum, varies in the same degree; and thus, when supplied with appropriate nutriment, Man is able to brave the severest cold, without suffering any considerable depression in his bodily temperature. It would seem that the Cutaneous Respiration (§ 317), small as its amount is, promotes those molecular changes on which the maintenance of Animal Heat depends; for it was found by MM. Becquerel and Breschet,† that when the hair of Rabbits was shaved-off, and a composition of glue, suet, and resin (forming a

* The Author has stated the very striking results of observations which he has had the opportunity of making upon this point, in his Essay "The Physiology of Temperance and Total Abstinence," § 213

† "Comptes Rendus," Oct. 1841. These experiments have been repeated and confirmed by Magendie ("Gazette Médicale," Dec. 6, 1843).

coating impermeable to the air) was applied to the whole surface, the temperature rapidly fell, notwithstanding the obstacle thus offered to the evaporation of the sweat, whereby, it might be supposed, the temperature of the body would be considerably elevated. In the first rabbit, which had a temperature of 100° before being shaved and plastered, it had fallen to 89½° by the time the material spread over him was dry. An hour afterwards, the thermometer placed in the same parts (the middle of the thigh and chest) had descended to 76°. In another rabbit, prepared with more care, by the time that the plaster was dry, the temperature of the body was not more than 5½° above that of the surrounding medium, which was at that time 69½°; and in an hour after this, the animal died. —These experiments place in a very striking point of view the importance of the cutaneous surface as a respiratory organ, even in the higher animals; and they enable us to understand how, when the aerating power of the Lungs is nearly destroyed by disease, the heat of the body is kept-up to its natural standard by the action of the Skin. A valuable therapeutic indication, also, is derivable from the knowledge which we thus gain, of the importance of the cutaneous respiration; for it is easy to perceive the desirableness of keeping the skin moist, in those febrile diseases in which there is great heat and dryness of the surface, since aeration cannot properly take place through a dry membrane. Of the relief afforded by cold or tepid sponging in such cases, experience has given ample evidence.

437. It has been held that the Chemical theory of Calorification is insufficient to account for the total amount of Heat generated by a warm-blooded animal in a given time; this assertion being founded upon the experimental results obtained by M. Dulong. MM. Fabre and Silbermann* have shown, however, that the original estimates require correction for the true calorific equivalents of carbon and hydrogen, and that this correction having been made, the heat produced by the combustion of the Carbon which is contained in the carbonic acid expired, and by the combustion of such a proportion of the Hydrogen contained in the exhaled water as may be fairly considered to have undergone oxygenation within the system (§ 321), proves to be adequate to compensate for that which would be dissipated by the evaporation of all the water transpired from the skin and lungs, and also to maintain the temperature of the body itself in an atmosphere of ordinary coolness. And to the combustion heat of carbon and hydrogen, we should also add that of those relatively-minute quantities of Phosphorus and Sulphur, which also undergo oxidation within the system (§ 414), whereby a small additional amount of heat must be generated.—Through whatever diversity of combinations or successive stages of oxidation these elements respectively pass, in their progress to complete or final oxidation, it may be regarded as an indisputable fact, that *they give-out precisely the same amount of heat in the whole, as if they had undergone the most rapid combustion in pure oxygen*; and thus we may look to almost every molecular change in the body, although pre-eminently to those which are concerned in the *disintegration* of its textures and in the elimination of their products by Respiration, as participating in the function of Calorification.

* See their Memoir 'Des Chaleurs de Combustion,' in "Compt. Rend.," tom. xx., [illegible]

438. It cannot be denied, however, that there are certain phenomena which seem at first sight to be completely opposed to this doctrine, and which can scarcely be explained in accordance with it, save by a considerable modification in our usual ideas. The class of facts to which reference is here made, are those which indicate that the Nervous System has a very important concern in the process, and that it is, in fact, one of the immediate instruments in the development of heat. Thus it was experimentally shown by Sir B. Brodie,* that when the Brain is cut-off from the spinal cord, or its functions are suspended by the agency of a narcotic, and artificial respiration is practised, so that the circulation is maintained, the body not only loses heat rapidly, but may even cool *more rapidly* than the body of an animal similarly treated, but in which artificial respiration is not performed. Now it is certainly true, as was subsequently pointed-out by Drs. Wilson Philip and Hastings,† and by Dr. C. Williams,‡ that the effect of the artificial performance of respiration depends in some degree upon the mode in which it is accomplished; for that if, as in most of Sir B. Brodie's experiments, the insufflation be repeated 30 times or more in a minute, the cooling effect of the air thus introduced is greater than the warming effect of the imperfect respiratory change to which it becomes subservient; whilst if the insufflation be repeated only 12 times in a minute, the cooling of the body, as compared with that of a body in which the circulation is not thus maintained, is retarded, instead of being accelerated. But still it is evident from Sir B. Brodie's experiments, that the withdrawal of the influence of the Encephalon has a positively-depressing effect upon the Calorific function; for the rapid fall of temperature took place even in cases, in which the amount of carbonic acid exhaled during the performance of artificial respiration was fully equal to the normal quantity; and the subsequent experiments of MM. Le Gallois§ and Chossat|| are decidedly confirmatory of this conclusion, whilst they extend it to other lesions of the Nervous centres, the influence of which upon the calorific function appears to be proportional to their severity.—Various pathological phenomena, moreover, indicate that the withdrawal of nervous influence from any part of the body usually tends to produce a depression of its temperature, and this especially in the extremities; thus Mr. H. Earle¶ found the temperature of paralysed limbs slightly lower than that of sound limbs; so Prof. Dunglison has noticed that in one case of hemiplegia of five months' standing, the temperature of the axilla was $96\frac{1}{2}°$ on the sound side, and 96° on the paralysed; whilst that of the hand was 87° on the sound side and only $79\frac{1}{2}°$ on the paralysed; and in another case of only a fortnight's duration, the temperature of the axilla was 100° on the sound side, and only $98\frac{1}{4}°$ on the paralysed, whilst that of the hand was 94° on the sound side, and 90° on the paralysed.**

439. It is a remarkable fact, however, that the disturbance of tempera-

* "Philosophical Transactions," 1811, 1812; and "Physiological Researches."

† See Dr. Wilson Philip's "Experimental Enquiry into the Laws of the Vital Functions," 3rd edit. p. 180.

‡ "Edinb. Med. Chir. Trans.," vol. ii. p. 192.

§ "Annales de Chimie," 1817; and "Œuvres de M. Le Gallois," tom. ii.

|| "Mémoire sur l'Influence de Système Nerveux sur la Chaleur Animale."

¶ "Medico-Chirurgical Transactions," vol. vii.

** "Human Physiology," 7th edit., vol. ii. p. 238

ture produced by severe injuries of the Nervous system, occasionally shows itself in the opposite direction. Thus it has been noticed by many experimenters, that one of the first effects of division of the spinal cord in the back, in warm-blooded animals, is to *raise* the temperature of the posterior part of the body, this elevation continuing for some hours. A case is recorded by Sir B. Brodie, in which, the spinal cord having been so seriously injured in the lower part of the cervical region that the whole of the nerves passing-off below were completely paralysed, the heat of the body, as shown by a thermometer placed on the inside of the groin, was not less than 111°; and this notwithstanding that the respiratory function was very imperfectly performed, the number of inspirations being considerably reduced, and the countenance being livid.* And Prof. Dunglison states that, notwithstanding the usual depression of the thermometer on the hemiplegic side, it is not unfrequently found to be more elevated than on the sound side.† According to the recent experiments of M. Cl. Bernard ‡ it appears that an elevation of temperature constantly takes place on one side of the face, when the trunk which unites the Sympathetic ganglia of the neck on that side is cut through; this increase being not only perceptible to the touch, but showing itself by a thermometer introduced into the nostrils or ears, even to the extent of from 7° to 11° Fahr. When the superior cervical ganglion is removed, the same effect is produced, and with yet greater intensity. This difference is maintained for many months, and is not apparently connected with the occurrence of inflammation, congestion, œdema, or any other pathological change in the tissues, though the sensibility of the parts thus affected is no less augmented than their temperature; moreover, it is not prevented from manifesting itself by the division of any of the cerebro-spinal nerves of the face. The fact, however, appears to be sufficiently explained by the relaxation of the walls of the smaller arteries (producing a state resembling a permanent 'blush'), and the consequent increase in the afflux of blood to the part, which has been shown by Dr. Aug. Waller to result from this operation. (See § 257.)

440. The influence which conditions of the Nervous System are thus shown to possess over the function of Calorification, has led some Physiologists and even Chemists to the conclusion, that the production of Heat is essentially dependent upon Nervous agency, of which it is one of the manifestations. But, as Prof. Liebig justly observes, "if this view excludes chemical action, or changes in the arrangement of the elementary particles, as a condition of nervous agency, it means nothing else than to derive the presence of motion, the manifestation of force, from nothing. But no force, no power, can come of nothing."§ That the production of heat in living bodies may take place without any possible assistance from Nervous agency, is manifest from the phenomena of Vegetable heat (See PRINC. OF COMP. PHYS., § 439); and there can be no reasonable doubt that the source of this production is a true combustive process. And the evidence afforded by the post-mortem production of heat in the Human subject (§ 428) conclusively points to the same result; more particularly

* "Medical Gazette," June, 1836; and "Physiological Researches," p. 121.

† "Amer. Med. Intelligencer," Oct. 15, 1838.

‡ "Gazette Médicale," Fevr. 21, 1852.

§ "Animal Chemistry," 3rd edit., p. 39.

as the elevation of temperature observed in the brain was uniformly *less* than that which was manifested in other large organs.—But the phenomena just enumerated (and many others that might be cited) can scarcely be accounted-for, without admitting that the Nervous system exerts an important modifying power upon the temperature of the body, which may be either elevated or depressed through its agency; and the question now arises, whether this operation takes place through the influence which the Nervous system exerts over the molecular processes of Nutrition, Secretion, &c., or through some more direct method. It can scarcely be denied that the first of these channels affords not merely a possible, but also a probable means, for the exercise of such influence; but still it is difficult to conceive that any great effect can be thus produced, since, as already shown, it is not so much in the growth as in the disintegration of textures, that heat is produced by the oxidation of their components. On the other hand, from the close relation which exists between the Vital and the Physical forces (See PRINC. OF GEN. PHYS.), it can scarcely be regarded as improbable that the Nervous force, generated by molecular changes in the Nervous substance, may manifest itself under the form of Heat, just as we know that it manifests itself (in the electric Fishes, &c.) under that of Electricity.* And thus it is quite conceivable, that one mode in which alimentary materials may be applied to the maintenance of Animal Heat, may consist in their subservience to these molecular changes, which seem to take place in the Nervous substance with more activity than in any other tissue; and thus a large measure of caloric may be generated through the immediate instrumentality of the Nervous system, notwithstanding that the ultimate source of its development lies (as in the Chemical theory) in the oxidation of the elements of the food. —Such an hypothesis will be found consistent, the Author believes, with all the well ascertained facts of the case; for whilst it assigns their full value to all those proofs, which establish (in his mind) the necessary dependence of Calorification upon the changes to which the Respiration is subservient, and thus upon the supply of combustive material on the one hand and of oxygen on the other, it also assigns a definite *modus operandi* to the Nervous system, as an instrument largely concerned in the production and distribution of the heat thus generated,—this *modus operandi*, moreover, being in such complete harmony with the other manifestations of Nervous power, that its existence might almost have been predicated upon general considerations.†

441. We have now to inquire whether the *power of generating Heat* is possessed by the Human subject in an equal degree at all ages; this question being very different from that of the *ordinary temperature* of the body at the various periods of life; since an individual who can maintain a high temperature when the surrounding air is moderately warm, may have very little power of bearing continued exposure to severe cold. Important analogical evidence on this point has been supplied by the experiments of Dr. W. F. Edwards upon the lower Mammalia, Birds, &c.‡ It appears from these to be a general fact, that, the younger

* See "Princ. of Comp. Phys.," §§ 461–466.

† See the Author's Memoir 'On the Mutual Relations of the Vital and Physical Forces,' in "Phil. Trans.," 1850.

‡ "On the Influence of Physical Agents on Life," part iii. chap. i.

the animal, the less is its independent calorifying power. Thus the development of the embryo of all Oviparous animals is entirely dependent upon the amount of external warmth supplied to it. There are many kinds of Birds, which, at the time they issue from the egg, are so deficient in the power of generating heat, that their temperature rapidly falls when they are removed from the nest and placed in a cold atmosphere; it being shown by collateral experiments, that the loss of heat was not to be attributed to the absence of feathers, nor to the extent of surface exposed in comparison with the bulk of the body; and that nothing but an absolute deficiency in the power of generating it, would account for the fall of temperature. This is quite conformable to facts well ascertained in regard to Mammalia. The fœtus, during intra-uterine life, has no power of keeping-up its own temperature; and in many cases it is much dependent on external warmth, for some time after birth. The degree of this dependence, however, differs greatly in the various species of Mammalia, as among Birds; being less, in proportion as the general development is advanced. Thus, young Guinea-pigs, which can run-about and pick-up food for themselves, almost as soon as they are born, are from the first independent of parental warmth; whilst on the other hand the young of Dogs, Cats, Rabbits, &c., which are born blind, and which do not, for a fortnight or more, acquire the same development with the preceding, rapidly lose their heat when withdrawn from contact with the body of the mother.

442. In the Human species, it is well known that external warmth is necessary for the Infant, its body rapidly losing heat when exposed to the chilling influence of a low temperature; but the fact is too often neglected (under the erroneous idea of 'hardening' the constitution) during the early years of childhood. It is to be carefully remembered that the development of Man is slower than that of any other animal, and that his calorifying power is closely connected with his general bodily vigour; and though the infant becomes more independent of it as development advances, it is many years before the standard can be maintained without assistance, throughout the ordinary vicissitudes of external temperature. Especial care is required with regard to the maintenance of the bodily heat by artificial warmth, in the case of children prematurely born; for the earlier the period of embryonic life, the less is the power of calorification that exists for some time after birth. The temperature of a seven months' child, though well swathed and near a good fire, was found by Dr. W. Edwards, within two or three hours after its birth, to be no more than 89·6°. And in some of the recorded instances in which the birth has taken place before the completion of the sixth month, it has not been found possible to maintain the warmth of the infant by exposure to the radiant heat of a fire, the contact of the warm body of another person being the only effectual means of keeping up its temperature.—The fullest measure of calorifying power is possessed by adults; but even in them it is sometimes weakened by previous exertion, so that death by the cooling of the body may occur, when the body is exposed to cold of no great intensity, but in a state of exhaustion of nervous power; a fact which remarkably confirms the views advanced in the preceding paragraph. A decrease of calorifying power takes place in advanced age. Old people complain that their "blood is

chill;" and they suffer greatly from exposure to cold, the temperature of the whole body being lowered by it.

443. These facts have a very interesting connection with the results of statistical inquiries, as to the average number of deaths at different seasons; the following are recorded by M. Quetelet,* as occurring at Brussels, the *mean* monthly mortality at each age being reckoned as 100.

	First Month.	2—3 Years	8—12 Years.	25—30 Years.	50—65 Years.	90 Years and above.
January	1·39	1·22	1·08	1·05	1·30	1·58
February	1·28	1·13	1·06	1·04	1·22	1·48
March	1·21	1·30	1·27	1·11	1·11	1·25
April . .	1·02	1·27	1·34	1·06	1·02	0·98
May	0·93	1·12	1·21	1·02	0·93	0·84
June . . .	0·83	0·94	0·99	1·02	0·85	0·75
July	0·78	0·82	0·88	0·91	0·77	0·64
August . . .	0·79	0·73	0·82	0·96	0·85	0·66
September . .	0·86	0·76	0·81	0·95	0·89	0·76
October	0·91	0·78	0·76	0·93	0·90	0·74
November	0·93	0·91	0·80	0·97	1·00	1·03
December	1·07	1·01	0·96	0·97	1·15	1·29

We see from this table that, during the first months of infant life, the external temperature has a very marked influence; for the average mortality during each of the three summer months being 80, that of January is nearly 140, and the average of February and March is 125. This is confirmed by the result obtained by MM. Villermé and Milne-Edwards, in their researches on the mortality of the children conveyed to the Foundling Hospitals in the different towns in France; for they not only ascertained that the mortality is much the greatest during the first three months in the year, but also that it varies in different parts of the kingdom, according to the relative severity of the winter.† As childhood advances, however, the winter mortality diminishes, whilst that of the spring undergoes an increase; this is probably due to the greater prevalence of certain epidemics at the latter season; for the same condition is observed, in a still more remarkable degree, between the ages of 8 and 12 years,—the time when children are most severely affected by such epidemics. As the constitution acquires greater vigour, and the bodily structure attains its full development, the influence of the season upon mortality becomes less apparent; so that at the age of from 25 to 30 years, the difference between the summer and winter mortality is very slight. The difference reappears, however, in a very marked degree, at a later period, when the general vigour, and the calorifying power, undergo a gradual diminution. Between the ages of 50 and 65, it is nearly as great as in early infancy; and it gradually becomes more striking, until, at the age of 90 and upwards, the deaths in January are

* "Essai de Physique Sociale," tom. i. p. 197.

† Dr. Emerson has shown that, in the Southern and Middle States of North America, the *high summer* temperature is the greatest cause of Infant mortality, the proportion of deaths during the first year of childhood, occurring in the months of June, July, and August, being about *four* times greater than that occurring during the same months in any subsequent year up to the age of 20. The *winter* mortality under the second year scarcely exceeds the average of subsequent years. ("Amer. Jour. of Med. Sci.," Nov. 1831)

158, for every 74 in July (a proportion of $2\frac{1}{4}$ to 1); and the average of the three winter months is 145, whilst that of the three summer months is only 68, or less than one-half. The results of the comparisons which have now been carried-out for many successive years, in the Reports of the Registrar General, between the variations in the weekly rate of mortality in the Metropolis and the range of atmospheric temperature, present a close coincidence with the foregoing; it being especially to be noted, that the rate of mortality (save during the prevalence of any fatal epidemic) is almost invariably the highest during the winter months, that the increase of deaths at that period is most marked amongst children and old people, and that any extraordinary severity of winter cold constantly produces a great augmentation in the mortality, the weekly number of deaths rising from the average of 1000 (or thereabouts) to 1200, when the mean temperature of the twenty-four hours remains a degree or two below the freezing point.

444. Having thus considered the means by which the degree of Heat necessary for the performance of the functions of the Human system is generated, we have to inquire how its temperature is prevented from being raised too high; in other words, what *frigorifying* means there are, to counterbalance the influence of causes, which in excess would otherwise be fatal, by raising the heat of the body to an undue degree (§ 436). How is it, for example, that, when a person enters a room whose atmosphere is heated to one or two hundred degrees above his body, the latter does not partake of the elevation, even though exposed to the heat for some time? Or, since the inhabitants of a climate, where the thermometer averages 100° for many weeks together, are continually generating additional heat in their own bodies, how is it that this does not accumulate, and raise them to an undue elevation?—The means provided by Nature for cooling the body when necessary, are of the simplest possible character. From the whole of its soft moist surface, simple *Evaporation* will take place at all times, as from an inorganic body in the same circumstances; and the amount of this will be regulated merely by the condition of the atmosphere, as to warmth and dryness. The more readily watery vapour can be dissolved in atmospheric air, the more will be lost from the surface of the body in this manner. In cold weather, very little is thus carried-off, even though the air be dry; and a warm atmosphere, already charged with dampness, will be nearly as ineffectual. But simple evaporation is not the chief means by which the temperature of the body is regulated. The Skin, as already mentioned (§ 421), contains a large number of glandulæ, the office of which is to secrete an aqueous fluid; and the amount of this *Exhalation* appears to depend solely or chiefly upon the *temperature* of the surrounding air. Thus, when the external heat is very great, a considerable amount of fluid is transuded from the skin; and this, in evaporating, carries-off a large quantity of the free caloric, which would otherwise raise the temperature of the body. If the atmosphere be hot and dry, and also be in motion, both exhalation and evaporation go-on with great rapidity. If it be cold, both are checked, the former almost entirely so; but, if it be dry, some evaporation still continues. On the other hand, in a hot atmosphere, saturated with moisture, exhalation continues, though evaporation is almost entirely checked; and the fluid poured-out by the

exhalant glands accumulates on the skin. There is reason to believe that the secretion continues, even when the body is immersed in water, provided its temperature be high. —We learn from these facts the great importance of not suddenly checking Exhalation, by exposure of the surface to cold, when the secretion is being actively performed; since a great disturbance of the circulation will be likely to ensue, similar to that which has been already mentioned, as occurring when other important secretions are suddenly suspended.

3. *Evolution of Light.*

445. Although the evolution of Light from the living Human subject is an exceptional phenomenon, which has only been observed in morbid states of the body, yet its occasional occurrence is fraught with interest to the Physiologist, on the one hand from its relation to the Luminosity so common among the lower animals, and on the other from the indications which it affords of the possibility of the formation, even during life, of peculiar phosphuretted compounds, which, being products of incipient decomposition, have been usually supposed to be generated only after death.—There is no doubt that luminous exhalations frequently ascend from burial-grounds; and that the superstitions of many nations respecting 'corpse-lights' have to this extent a foundation in fact. A very decided luminosity has been observed to proceed from dissecting-room subjects, the light thus evolved being sufficient to render the forms of the bodies, as well as those of muscles and other dissected parts (which are peculiarly bright), almost as distinct as in the daylight. That this proceeds from the production of a peculiar phosphorescent compound, is shown by the fact, that the luminosity may be communicated to the fingers or to towels, &c., by contact with the luminous surfaces.*—Dr. W. Stokes narrates the case of a patient who was under his observation, some years since, in the Old Meath Hospital, having been admitted on account of an enormous cancer in her breast, which was in an advanced stage of ulceration, the edges being irregular and everted; every part of the base and edges of this cavity was strongly phosphorescent, the light being sufficient to enable the figures on a watch-dial to be distinguished within a few inches; and here also it appeared that the luminosity was due to a particular exudation from the exposed surface. Three cases are recorded by Sir H. Marsh, in which an evolution of light took place from the living body, without any such obvious source of decomposition; all the subjects of these cases, however, were in the last stage of phthisis, and it can scarcely be doubted that here, as in other diseases of exhaustion, incipient disintegration was taking place during the later periods of life (§ 72). The light in each case is described as playing around the face, but not as directly proceeding from the surface; and in one of these instances, which was recorded by Dr. D. Donovan,† not only was the luminous appearance perceptible over the head of the patient's bed, but luminous vapours passed in streams through the apartment. It can

* See Sir Herbert Marsh on "The Evolution of Light from the Living Human Subject," (Dublin, 1842), p. 20.—From this interesting pamphlet, most of the statements in this paragraph are derived.

† "Dublin Medical Press," Jan. 15, 1840.

scarcely be doubted that it was here the *breath*, which contained the luminous compound, more especially as it was observed in one of the cases to have a very peculiar smell; and the probability that the luminosity was due to the presence of phosphorus in progress of slow oxidation, is greatly increased by the fact already referred to (§ 441), that the injection of phosphuretted oil into the blood-vessels gives rise to a similar appearance. In repeating this experiment, Sir H. Marsh states that when half an ounce of olive-oil, holding two grains of phosphorus in solution, was injected into the crural vein of a dog, a dense white vapour began to issue from the nostrils even before the syringe was completely emptied, which became faintly luminous on the removal of the light; and the injection being repeated with the same quantity, the expiration immediately became beautifully luminous, resembling jets of pale-coloured flame pouring forth from the nostrils of the animal. And the luminosity which has been occasionally observed in the urine,* may then be imputed to an increase in the quantity of unoxidized phosphorus which it seems normally to contain (§ 413); its liberation taking-place at a more rapid rate than its conversion into phosphoric acid (§ 414), either through excessive excretion or through impeded respiration.† A case has been recorded by Kaster (loc. cit.) in which the body-linen was rendered luminous by the perspiration, after any violent exercise; and here, too the cause may be presumed to have been the same.—On the whole then we may conclude the occasional evolution of Light from the Human subject, to be the consequence (when not an *electrical* phenomenon) of the production of a phosphorescent compound at the expense of the disintegrating tissues, which compound passes-off through one of the ordinary channels of excretion.

4. *Evolution of Electricity.*

446. When the vast variety of changes of condition to which the components of the living body are subjected during the performance of its vital operations, and the impossibility of the occurrence of any of these without some disturbance of Electric equilibrium,‡ are duly considered, the wonder is, not that such disturbance should be occasionally

* "Casper's Wochenschrift," 1849, No. 15.—A case has been recently put on record (Büchner's Repert. B. viii. p. 342), in which the urine and semen of a patient who was under treatment for impotence and spermatorrhœa, and who was employing phosphorus as a remedy both internally and externally, were observed to be luminous.

† The large proportion of intemperate subjects, among those who exhibit this phenomenon, seems to confirm the view already expressed, that the habitual presence of Alcohol in the blood interferes with the oxidation and elimination of excrementitious matters.

‡ There is probably no instance of *chemical union* or decomposition, in which the electric condition of the bodies concerned is not altered. Simple *change of form*, from solid to liquid, or from liquid to gaseous, is attended with electric disturbance; and this is greatly increased when any separation takes place between substances that were previously united, as when water containing a small quantity of saline matter is caused to evaporate and to leave it behind. *Heat*, again, is continually generating Electricity; for not only is a current produced by the heating of two dissimilar metals in contact, but also by the unequal heating of two parts of the same bar; and though the effect is most striking in the case of metals, it is by no means limited to them. And so constantly is Electricity generated by the interruption of *motion*, as in friction, that it is not possible to rub together any two substances, excepting those which are of the most perfect homogeneity (such as the fractured surfaces of a broken bar), without the production of Electric change, as well as of Heat.

so considerable as to make itself apparent, but that it should be ordinarily so obscure as only to be detected by the most careful search, and with the assistance of the most delicate instruments. The researches of Prof. Matteucci, M. du Bois-Reymond, and others, however, have now made it apparent, that there are no two parts of the body (save those which correspond on the opposite sides), whose electrical condition is precisely the same; and that the differences between them are greater in proportion to the diversity of the vital processes which are taking-place in them, and to the activity with which these are being carried-on.*— It is by the comparison of the electric states of different Secreting surfaces, that such departures from equilibrium are most readily demonstrated. Thus, Donné found that the skin and most of the internal membranes are in opposite electrical states; and Matteucci observed a considerable deflection of the needle of a delicate galvanometer, when the liver and stomach of a rabbit were connected with its platinum electrodes.† More recently, Mr. Baxter has found that if one of the electrodes be placed upon any part of the intestinal surface, and the other be inserted into the branch of the mesenteric vein proceeding from it, a decided deflection of the needle was produced, indicating a positive condition of the blood; but that no effect was produced, when the second electrode was inserted into the artery of the part, instead of into its vein. These effects were found to cease after the death of the animals: and could not be attributed, therefore, to mere chemical differences between the blood and the secreted product; but must have arisen from electric disturbance taking-place in the very act of secretion.‡—That the process of Nutrition, as well as of Secretion, in parts which are undergoing rapid molecular change, gives-rise to electric disturbance, is proved by the experiments of Matteucci and Du Bois-Reymond, upon the relative electrical states of different parts of muscles and nerves. If the two extremities of a Muscle, removed from the body of an animal very recently killed, be applied to the two electrodes of a delicate galvanometer, there is usually some deflection of the needle, this being greater, in proportion to the difference in the arrangement of the muscular and tendinous elements at the two extremities. Although the direction of the current is constant for each muscle, yet there is no constant relation between the direction of the currents and the position of the muscles in the body; thus in the *gastrocnemius* of the Frog's leg, the direction is from the foot towards the body, whilst in the *sartorius* it is the reverse. Taking all the muscles of a part together, however, there is usually such a want of balance between the opposite currents, that a constant current is established in the direction of the strongest and most numerous of the separate muscular currents; this, in the Frog, passes uniformly from the hind-feet towards the head, and was at one time supposed to be peculiar to that animal; but a similar current may almost always be detected in other animals. The muscular current grows feebler and feebler, the

* Having had an opportunity of witnessing some of the experiments made by M. du Bois-Reymond with a magneto-electrometer of extraordinary sensitiveness, the Author can bear his personal testimony to the fact, that the electricity even of the corresponding fingers of the two hands is very seldom equally balanced, and that the existence of even the slightest scratch or abrasion of surface upon one of them produces a very marked disturbance

† See M. Becquerel's "Traité de l'Electricite," tom. i. p. 327, and tom. iv. p. 300.

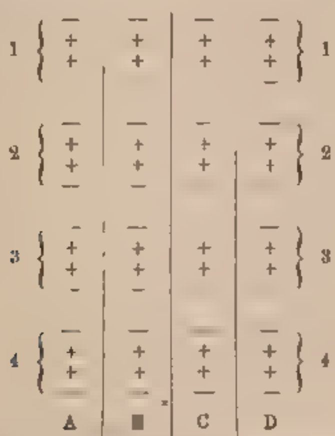
‡ "Philosophical Transactions," 1848, p. 243.

longer the muscle has been removed from the body; it is affected by any agents which tend to lower its vitality, and becomes extinct as soon as its contractility ceases. From the experiments of M. du Bois-Reymond, to be presently described (§ 450), it may be concluded that the current in the arm of Man, when at rest, is from the shoulder towards the points of the fingers.

447. The conditions of the 'Muscular current' have been made the subject of special investigation by M. du Bois-Reymond; and the following is an outline of the results at which he has arrived, for whose due comprehension, however, it is requisite that the terms employed by him should be first defined.—The entire muscle being composed of a mass of fibres, having a generally-parallel direction, and attached at their extremities to tendinous structure (which has in itself but little or no electromotor power, but is a conductor of electricity), it follows that the tendon or tendinous portion of a muscle represents a surface formed by the bases of the muscular fibres considered as prisms, which may be designated as *natural transverse section*. On the other hand, the fleshy surface of the muscle, which is formed only by the *sides* of the fibres considered as prisms, may be regarded as the *natural longitudinal section* of the muscle. Again, if a muscle be divided in a direction more or less perpendicular to its fibres, an *artificial transverse section* will be made; whilst if the muscle be torn lengthways in the direction of its fibres, an *artificial longitudinal section* will be made; and these artificial sections show the same electric conditions with their corresponding natural sections. Now experiments repeated in a great variety of modes demonstrate, that *every point in the natural or artificial longitudinal section of a muscle is positive in relation to every part of its transverse section, whether natural or artificial:* the most powerful influence on the galvanometer being produced, when a portion of the surface (or natural longitudinal section) of a muscle is laid upon one of the electrodes, and a portion of the surface formed by cutting the muscle across (or artificial transverse section) is placed against the other. When the two tendinous extremities of a muscle whose form is symmetrical or nearly so, are placed against the electrodes, the deflection of the needle of the galvanometer is but slight; and the same is the case with two transverse sections taken at equal distances from the two ends of the muscle, and also with two points of the longitudinal section which are equally distant from the middle of its length. But if the two points of the longitudinal section applied to the electrodes, be not equally distant from the centre of the muscle, then the point which is nearest to the centre is positive to the one which is nearest to the end; and, in like manner, when the different parts of the transverse section are tested in regard to each other the points lying nearest the surface of the muscle, are found to be positive to those nearest its interior. The intensity of the current, however, between any two points in the *same* section —whether transverse or longitudinal— is always incomparably less than that of the currents which are obtained between two points in *different* sections, one in the longitudinal and the other in the transverse.

448. These results may be obtained, not merely with the entire Muscle, but with insulated portions of it, and even, as we are assured by M. du Bois-Reymond, with a single primitive fasciculus. Hence it seems un-

questionable, that every integral particle of the muscular substance must be a centre of electro-motor action, and must contain within itself positive and negative elements; and the variations both of intensity and direction in the muscular current, under certain circumstances, are so sudden and so extensive, that it appears impossible to account for them by any change of larger heterogeneous elements, or in any other way than by assuming corresponding changes of position in almost infinitely small centres of action. It is indifferent what form is assigned to these electromotive molecules; but it would seem that they must have two negative polar zones, and a positive equatorial zone; a combination of such elements being able to produce all the electrical effects of a muscle in a state of rest. It seems altogether best to suit the phenomena, to suppose that each of these *peripolar* molecules is formed by the combination of two *dipolar* molecules, touching each other by their positive poles, —as in the subjoined table, which represents a band of four series, A, B, C, D, each series containing four dipolar molecules.



449. The current shown by the entire Muscle, when made to form part of a circuit, is only a *derived* current produced by incomparably more intense currents circulating in the interior of the muscle around these ultimate particles, and will vary greatly in intensity, according to the mode in which these particles are arranged; generally speaking, however, it increases both with the length and with the thickness of the muscle. There is, however, another cause of a very remarkable nature, which influences both its intensity and its direction; this, according to M. du Bois-Reymond, is the existence of a thin layer of muscular substance, beneath the tendinous expansion, whose electromotive power is exactly opposite to that of the rest, so that its action tends to reverse the general law of the muscular current. For when the *gastrocnemius* of a frog is placed between the two electrodes, so as to touch them only with its tendinous extremities, it gives a weak upward current; but if the frog have been previously cooled, there will probably be no current at all; or if it have been frozen, there may actually be a current in the opposite

direction. If, now, a drop of any liquid capable of corroding the muscular tissue (such as alcohol, creosote, acids, alkaline solutions, &c.) be placed upon the aponeurosis of the tendo Achillis, the ordinary upward current of the muscle is evolved, and the same effect is produced by completely removing a thin layer of muscular substance at the natural transverse section. This effect is accounted-for by M. du Bois-Reymond, on the supposition that at the tendinous extremities of the muscular fibres, the linear series of peripolar elements is terminated by a single dipolar element, whose positive pole is thus free, instead of the negative pole being so; and he has shown that by an apparatus of zinc and copper constructed after this plan, all the electric phenomena of the muscle at rest may be imitated.

450. That a change in the electric state of a Muscle takes-place in the act of contraction, had been ascertained by the experiments of Prof. Matteucci,* but as he was only able to detect this by the galvanoscopic frog (the galvanometer which he employed not giving unquestionable indications of it), he was not able to determine its nature with accuracy. This has been accomplished, however, by M. du Bois-Reymond; who has shown that during contraction the muscular current is not increased (as supposed by Matteucci), but is diminished and even reduced to zero. In order to exhibit this phenomenon satisfactorily, it is found advantageous to cause the muscle to contract powerfully or uninterruptedly for as long a time as possible, that is, to *tetanize* it, and this may be effected by acting violently on its nerve by heat, chemical agents, or a succession of electric shocks; or by poisoning the animal with strychnia. In whatever mode the tetanized state is induced, the same result follows,—the needle of the galvanometer passes-over to the negative side. This, however, does not indicate (as might be at first supposed) the development of a new current during the contraction, in a direction opposite to that which prevails during rest; but it is the consequence of the 'secondary polarity'† which is evolved in the platinum electrodes, as soon as the muscular current is diminished; the needle passing from the positive to the negative side, as soon as the current of the secondary polarity becomes more powerful than the original muscular current. This negative deflection of the needle at the moment of contraction, is always proportionate to the actual intensity of the current of the muscle while at rest, and it ceases as soon as the tetanic contraction ceases, after which the muscular current gradually recovers its previous intensity.

451. Thus, then, it appears that the Contraction of a Muscle is attended

* See his successive Memoirs in "Philos. Transact.," for 1845, 1847, and 1850.

† When the electromotor body is removed, and the two electrodes (platinum plates immersed in a saturated solution of common salt), are connected by some imperfectly conducting body, a secondary current is manifested in the reverse direction to the first, the needle being deflected to the other side; this is caused by the electro-chemical reaction of the substances which the current of animal electricity has evolved on the platinum plates by means of its electrolytic action; and its occurrence is often a useful and valuable confirmation of the first result, as showing that the primary deflection really was the consequence of the presence of an electromotor. When the electromotive action, moreover, is very weak, it may be made more evident by reversing the position of the electromotor, without first replacing the connecter, so that the action which it will then exert in the reverse direction, will be strengthened by the secondary current developed by the previous action.

with *a marked diminution of its electromotive power;* a fact which seems to harmonize well with the general views already adverted-to in regard to the 'Correlation of Forces;' the changes which operate to produce disturbance of electric equilibrium whilst the muscle is at rest, being concerned in the development of motor power when it is thrown into contraction. This alteration has been demonstrated by M. du Bois-Reymond in the living animal, after the following manner. The two feet of a live frog were immersed in the two connecting vessels, but one of the legs was paralyzed by division of its sciatic plexus; the muscular currents of the muscles of the two limbs neutralized each other, so long as they remained at rest; but upon the frog being poisoned with strychnia, so that tetanic convulsions occurred in one limb whilst the other remained motionless, the current in the former limb was weakened, whilst that of the other remained unaffected, and a deflection of the needle took place, indicating an upward current in the paralyzed limb and a downward current in the tetanized one. The same thing may be shown in the Human subject, by dipping the forefingers of the two hands into the two conducting vessels connected with the galvanometer, so that the two arms are included in opposite directions in the circuit; when if, after the needle (which usually undergoes a temporary disturbance on their first immersion) has come to a state of rest, all the muscles of one of the arms be strongly and permanently contracted, so as to give them the greatest possible tension without changing the position of the arm, the needle is instantly deflected, always indicating a current from the hand to the shoulder, that is, an *upward* current in the contracted arm. Hence, according to the explanation just given, the contracted arm plays the part of the negative metal in the circuit, in regard to the arm whose muscles remain in the state of relaxation, showing that the normal current will be a downward one.—This change, however, is so extremely slight, that a very delicate galvanometer is requisite to render it perceptible. Its intensity depends very much on the muscular energy of the experimenter; and even the greater power which the right arm usually possesses, becomes perceptible in the greater deflection of the needle when it is put in action.*

452. The discovery that an electric current exists in *Nerves*, the conditions of which are in most respects similar to that of the Muscular current, is entirely due to M. du Bois-Reymond. When a small piece of a nerve-trunk is cut-out from the recently-killed body, and is so placed upon the electrodes that it touches one of them with its surface (or natural *longitudinal* section), and the other with its cut extremity (or artificial *transverse* section), a considerable deflection of the index is produced, the direction of which always indicates the passage of a current from the interior to the exterior of the nerve-trunk. It is indifferent in

* Of this very remarkable experiment, which was first made by M. du Bois Reymond, the Author has himself (through that gentleman's kindness) been a witness; and he cannot entertain the least doubt as to the *genuineness* of the phenomenon. The success of M. du Bois Reymond in these and similar investigations, is doubtless due in great part to the marvellous sensitiveness of the galvanometer he employs, the coils of which consist of *three miles* of wire, as well as to the perfection of the various arrangements by which he is enabled to avoid or eliminate sources of error; but it must be attributed in great part also to the philosophic method on which his inquiries are planned, and to the skill and perseverance with which they are carried-out.

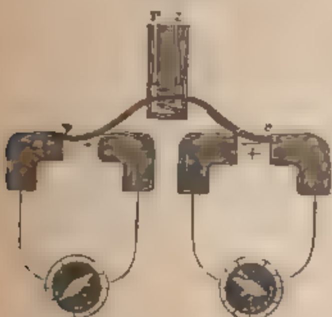
regard to the direction of the current, whether the central or the peripheral cut extremity be applied to the electrode; and in fact the most powerful effect is obtained by doubling the nerve in the middle, and applying both transverse sections to one electrode, whilst the loop is applied to the other. On the other hand, if the two cut extremities be applied to the two electrodes respectively, no decided effect is produced: and the same neutrality exists between any two points of the surface of the trunk, equidistant from the middle of its length; but if the points be not equidistant, then a slight deflection is produced, indicating that the parts nearer the middle are positive to those nearer the extremities. It has not been found possible, owing to the small size of the nerve-trunks experimented-on, to test in a similar manner the relative state of different points of their transverse section; but there can be little doubt, from the complete conformity which exists in other respects between the nervous and muscular currents, that the same law will be found to prevail in this as in the former case; namely, that the points nearer the surface are positive to those nearer the centre. There is no difference between the motor and the sensory nerves in regard to the direction of this current, the existence of which has been proved by M. du Bois-Reymond not only by the galvanometer, but also by the excitement of contractions in the limb of the galvanoscopic frog.—The 'nervous current,' like the muscular, must be considered as derived from the electromotive action of the molecules of the nerve; and, for the reasons already pointed out, the intensity of the current in the immediate neighbourhood of the molecules, may be infinitely greater than that which is shown by the galvanometer to exist in the trunk of the nerve.

453. We have now to follow M. du Bois-Reymond through his investigations on the change in the condition of the 'nervous current,' while the nerve is in a state of functional activity, whether motorial or sensorial. For the examination of this, it is desirable to induce a state of continuous action in the nerve, analogous to the tetanic contraction of muscle; and this condition in the motor nerve is manifestly that which induces tetanus in its muscle, whilst in sensory nerves it is that in which a violent sensation is uninterruptedly kept-up. No means of exciting such a state are so certain and simple as electric currents; but it is necessary in the first place to determine the modification which these currents may themselves produce in the proper 'nervous current.' If a portion of nerve-trunk be so placed (Fig. 75), that it touches one of the electrodes by its transverse section (which may be designated T), and the other by its surface or longitudinal section (L), and a portion of its continuation be included in a galvanic circuit, so that a current shall pass in the direction Z—P, which is the same in its direction as that between T—L, then the intensity of the 'nervous current' T—L, as indicated by the deflection of the needle of the galvanometer, will be found to undergo an increase; whilst on the other

FIG. 75.

hand, if the electric current be passed in the contrary direction P—Z, the intensity of the 'nervous current' T—L will decrease.—The portion Z—P of the nerve, which is included in the electric circuit, is termed the *excited* portion, and the current passed through it is the *exciting current*, on the other hand, the portion T—L included between the electrodes of the galvanometer, is the *derived* portion; and the altered condition of this part, which is produced by the extraneous current (this current having been experimentally proved by M. du Bois-Reymond to exert no influence of its own on the galvanometer), is termed the *electrotonic state* of the nerve. When the intensity of the 'nervous current' is increased, the nerve is said to be in the *positive phase* of this electrotonic state; and when it is diminished, the nerve is in the *negative phase* of that state.—By a proper arrangement, the same exciting current may be made to produce the positive phase in one part of a nerve-trunk, and the negative phase in another. Thus if the two extremities of a nerve (Fig. 76, *p* and *c*), be so connected with two galvanometers, that both shall develope the 'nervous current,' and an intermediate portion be excited by the transmission of an electric current in the direction Z—P, the nervous current in the 'derived' portion *c* will be increased in intensity, whilst that in the portion *p* will be diminished.

Fig. 76.



454. Hence it may be inferred, that when any portion of the length of a nerve is traversed by an electric current, besides the usual electromotive action of the nerve, a new electro-motive action takes place in every point of the nerve, by a polarization of its electromotive elements, which action has the same direction as the exciting current itself; and a current is thus produced in the 'derived' portion, which is added to the original 'nervous current' at that end of the nerve at which the direction of this new current and of the nervous current coincide, and is subtracted at that end at which the directions are different. These variations in the intensity of the 'nervous current' continue as long as the 'exciting current' lasts, and immediately cease when the circuit of that current is broken. It is to the induction of the electrotonic state in the nerve supplying it, that the contraction of a muscle is due, which ensues on the completion of the circuit; and to the cessation of this state, that the muscular contraction is due which is consequent upon the interruption of the circuit. Hence the electrotonic changes in the condition of nerves may be observed without previously dividing them.—When, on the other hand, a nerve is 'tetanized' by passing an interrupted and alternating current through a portion of it, the effect is, as in the case of muscle, to produce a *diminution* in its own proper current; the needles of *both* galvanometers, in the arrangement last described, being deflected to the negative side, instead of one going back to zero and the other having its positive deflection increased, as happens when the 'excited portion'

is subjected to a continuous and uniform current. The same negative variation of the nervous current has been demonstrated by M. du Bois-Reymond in nerves tetanized by other means, as by the use of strychnia. And the phenomena both of the 'electrotonic state' and of the 'negative variation' are precisely the same, whether motor or sensory nerves be subjected to the experiment; thus making it appear that nerve-force may be transmitted in either direction along each of these orders of nerves.

455. A very remarkable modification of the 'nervous current' has been shown by M. du Bois-Reymond to follow severe injuries of the nerve, by mechanical, chemical, or thermal agencies. If, for instance, a piece of hot metal be brought near to the nerve without touching it, the nervous current will be seen to diminish rapidly, and to have its direction reversed, during which the property possessed by the nerve of conveying irritation to the muscle, though somewhat impaired, will not be destroyed; and if, whilst in this abnormal state, the nerve be divided, every transverse section is found neutral or positive to the longitudinal section, instead of negative. If the nerve-trunk be then placed between moist tissues, so as to recover its natural moisture, it will at the same time recover its usual electromotive power.*

456. Some of the most important parts of the body being thus in a state of constant *disequilibrium* with regard to each other, it is not surprising that the electric state of the whole should be ordinarily not in equilibrium with that of surrounding bodies. This difference, however, is usually prevented from manifesting itself, in consequence of the restoration of the equilibrium by the free contact which is continually taking place between them; and it is for the most part only when the Human body is insulated, that it becomes apparent. The galvanometer is then affected, however, by the contact of one of its electrodes with the person insulated, and the other with any neighbouring uninsulated body; and also by the contact of the electrode with the hands of two persons both insulated, who join their other hands together, a difference in the electrical state of the two individuals being thus indicated. The electricity of man is most frequently positive, and irritable men of sanguine temperament have more free electricity than those of phlegmatic character; the electricity of women is more frequently negative than that of men. There are persons who scarcely ever pull-off articles of dress which have been worn next the skin, without sparks and a crackling noise being

* The materials of several preceding paragraphs have been derived from the Abstract of M. du Bois Reymond's researches, by Dr. Bence Jones ("On Animal Electricity, being an Abstract of the Discoveries of Emil du Bois Reymond.") Having himself had the opportunity of witnessing a considerable number of the experiments above referred to, the Author feels it due to M. du Bois Reymond to state, that their results corresponded so completely with his predictions in every instance, as to prove that he had acquired a thorough mastery over the conditions of the phenomena. And he may mention the experimental demonstration of the 'nervous current,' as most fully satisfactory. It may be stated, with confidence, that the course of investigation which is being followed out by M. du Bois Reymond is one pre-eminently calculated to develope results of importance in Physiology; and the only one out of which definite indications in regard to the Therapeutic applications of Electricity can be expected to arise. A collection of laborious results in this last direction, entitled "De l'Electrisation localisée, et de son Application à la Physiologie, à la Pathologie, et à la Therapeutique," has just been published (Paris, 1855) by Dr. Duchenne de Boulogne. See also "Brit. and For. Med. Chir. Rev.," vols. iii. p. 373, and xv. p. [illegible]

produced: especially in dry weather, when the electricity of the body is retained, instead of being rapidly dissipated as it is by a damp atmosphere. The effect is usually heightened, if silk stockings and other silken articles have been worn, since these act as insulators. It is doubtless in part attributable to the friction of the articles of dress against each other and against the body; but we can scarcely doubt that it is partly due to the generation of electricity in the body itself, since it bears no constant relation to the former of these supposed causes. Thus a Capuchin friar is mentioned by Dr. Schneider,* who, on removing his cowl, always found a number of shining crackling sparks to pass from his scalp; and this phenomenon continued still perceptible after a three weeks' illness. The most remarkable case of the generation of Electricity in the Human subject at present known, was recorded some years since in America.† The subject of it, a lady, was for many months in an electric state so different from that of surrounding bodies, that whenever she was but slightly insulated by a carpet or other feebly-conducting medium, sparks passed between her person and any object she approached; when most favourably circumstanced, four sparks per minute would pass from her finger to the brass ball of the stove at the distance of 1½ inch. From the pain which accompanied the passage of the sparks, her condition was a source of much discomfort to her. The circumstances which appeared most favourable to the generation of the electricity, were an atmosphere of about 80°, tranquillity of mind, and social enjoyment, whilst a low temperature and depressing emotions diminished it in a corresponding degree. The phenomenon was first noticed during the occurrence of an Aurora Borealis, and though its first appearance was sudden, its departure was gradual. Various experiments were made, with the view of ascertaining if the electricity was generated by the friction of articles of dress; but no change in these seemed to modify its intensity.

CHAPTER XI.

OF THE FUNCTIONS OF THE CEREBRO-SPINAL NERVOUS SYSTEM.

1.—*General Summary.*

457. The Nervous System of Man, like that of all other Animals, is composed of *ganglionic centres* and *nerve-trunks*, the former being essentially composed of 'vesicular substance,' made-up of cells which may be spheroidal, fusiform, caudate, stellate, or of almost any variety of shape; the latter consisting entirely of 'nerve-fibres,' which, in their most completely-developed state, are tubular (See PRINC. OF GEN. PHYS.). All our knowledge of the structure and endowments of these two forms of tissue, renders it probable that they bear a *complementary* relation to each other, the Vesicular substance having for its office to *originate* changes, which it is the function of the Fibrous to *conduct*. And thus, by means

* "Casper's Wochenschrift," 1849, No. 15.
† "American Journal of Medical Sciences," January, 1838.

of the extensive ramifications of the nerve-trunks, and the power of instantaneous transmission which they possess, almost every part of the body is brought into such close relation with the central Sensorium, that impressions made even at the points most remote from it are immediately felt there (provided the nervous communication be perfect); whilst the influence of Mental states in determining movements, is exerted as speedily and surely upon the muscular apparatus. For the transmission of these two sets of impressions, the 'centripetal' and the 'centrifugal,' two distinct sets of fibres are provided, neither of which is capable of taking-on the function of the other; these are termed respectively the *afferent* and the *efferent*.* Of the mode in which the former terminate in the central organs towards which they pass, and in which the latter commence their course in these same organs, no general statement can as yet be made; but it is quite certain that, in many instances at least, there is an absolute continuity from one form of nerve-tissue to the other. Three principal modes have been ascertained, in which this may occur. Either a globular cell may give-off a single prolongation that becomes a fibre, as seen at *a*, Fig. 77; in which case the cell is said to be

Fig. 77

Microscopic Ganglion from Heart of Frog, showing at *a*, a *Unipolar Ganglionic Cell*.

Fig. 78.

Bipolar Ganglionic Cells and nerve-fibres from ganglion of 5th Pair in Lamprey.

'unipolar.' Or a ganglion-cell presents itself (as it were) in the course of a nerve-tube, having each of its extremities prolonged into a fibre, as shown in Fig. 78; in which case the cell is said to be 'bipolar.' The former of these arrangements seems to be more common in the nervous centres of Man and the higher Vertebrata; whilst the latter prevails in Fishes. But in certain parts of the nervous centres of Man, we meet with ganglionic cells sending out radiating prolongations to the number of three, four, five, six, or more, some of which are occasionally to be traced

* The 'afferent' nerves are commonly designated *sensory*, but this is not strictly correct, since they frequently convey impressions which do not give rise to sensations. The 'efferent' nerves, in like manner, though generally *motor*, are by no means necessarily so.

into continuity with the axis-cylinders of nerve-tubes, as seen at *a*, *b*, Fig. 79; whilst others, it is probable, inosculate with those of other stel-

FIG. 79.

Stellate Ganglionic Cell, from 'substantia ferruginea' of Human Brain; one of its prolongations, *a*, becoming continuous with the axis-cylinder of a double-contoured nerve-fibre, *b*

late cells. Whether more than one fibre ever arises from one of these vesicles, cannot yet be positively stated.—We should be by no means justified in concluding, however, that ganglionic cells have no other structural or functional relation to nerve-fibres, than that which they derive from such direct continuity. For there are indubitably many ganglionic cells, which are simple spheroids, lying among the nerve-tubes; whilst on the other hand, there are numerous instances in which fibres that enter the central organs, return by *loops*, without forming any closer connection with ganglion-cells, than that which their juxtaposition brings about. It cannot be thought probable, either that the simple spheroidal vesicles are destitute of physiological importance, or that nerve-fibres would thus pass-in amongst them, and return, if some purpose were not answered by their doing so. And we seem justified therefore, in looking at this as one of the regular modes in which the two elementary components of the Nervous System are brought into mutual action; the whole question, however, of the nature of that action, and of its diversities in the several cases just described, being one which is at present entirely open.

458. The general relations of the principal Centres of the Nervous System of Man, having been already considered (§§ 45—47), it is only requisite here to remark, that those which make-up the Cerebro-Spinal portion of the apparatus have such an intimate structural relation to each other, and so much more frequently act consentaneously than separately, that, notwithstanding the abundant evidence of the diversity of their respective endowments, there is considerable difficulty in the determina-

tion of their special functions; since the destruction or removal of any one portion of the Nervous system, not only puts a stop to the phenomena to which that portion is directly subservient, but so deranges the general train of nervous activity, that it often becomes impossible to ascertain by any such method, what is its real share in the entire performance.—In this difficulty, however, we may advantageously have recourse to the study of the structure and actions of those forms of the Nervous System presented to us among the lower animals, in which its ganglionic centres are less and less intimately connected, and in which, therefore, it is more easy to gain an acquaintance with their several endowments. And from an extensive survey of these, we seem able to deduce the following conclusions, which afford the most valuable guidance in the study of the Nervous System of Man:*—

I. The Nervous System, in its lowest and simplest form, may consist of but a single ganglionic centre,† with afferent and motor nerves; its function is essentially *internuncial*; impressions made upon the afferent fibres exciting respondent or 'reflex' movements in the muscles supplied by the motor, without any necessary intervention of consciousness. Such movements are properly distinguished as *excito-motor*.

II. A simple repetition of such ganglionic centres may exist to any extent, without heterogeneousness of function, or any essential departure from the mode of action just indicated; each of these centres may be specially connected by afferent and motor fibres with one segment or division of the body, and may minister peculiarly to *its* actions; but the several centres may be so intimately connected by commissural fibres, that an impression made upon the afferent nerves of any one of these may excite respondent motions in other segments.—This we see effected through the annular gangliated cord of the higher Radiata, and through the longitudinal gangliated cord of the Articulata, the disposition of the ganglia and of their connecting cords, having reference simply to the general plan of the body.

III. A higher form of Nervous System is that in which the multiplication of ganglionic centres has reference, not to the multiplication of similar parts which are to be alike supplied with nervous power, but to the exercise of a diversity of functions, through the instrumentality of different structures: thus, in the higher Articulated and Molluscous tribes, we find ganglionic centres specially set apart for the actions of deglutition and respiration, as well as for those of locomotion; but their *modus operandi* is still the same, these actions being all 'excito-motor;' that is, being performed through the 'reflex' agency of their several ganglionic centres, without the necessary intervention of consciousness. These centres are connected with each other commissurally, when they are required to act with consentaneousness; and it is frequently to be observed in the most developed forms of each type, that they come into actual coalescence, their functional distinctness being still indicated, however, by the distribution of their nerve-trunks.

* For a general view of the facts on which these conclusions are based, see "Princ. of Comp. Phys.," Chap. XIII.

† It may, perhaps, be doubted whether any Animal really exists, possessing such a nervous system, and yet not endowed with consciousness. It is quite certain, however, that animals do exist (the Tunicated Mollusca for example), in which the actions above referred to are the only ones of which we have any distinct evidence from observation of their habits.

IV. In all but the very lowest Invertebrata, the Nervous System includes, in addition to the foregoing, certain ganglionic centres, situated in the neighbourhood of the entrance to the digestive cavity, and connected with organs, which, from their more or less close resemblance to our own instruments of special sense, we conclude to be organs of sight, smell, hearing, &c. Now as we know from our own experience, that impressions made upon these organs produce no influence on our actions unless we become *conscious* of them, and as the Invertebrata possess no distinct ganglionic centres of a higher character, it seems to be a legitimate inference, that these 'sensorial' ganglia are the instruments by which the animals furnished with them are rendered cognizant of such impressions, and through which the sensations thus called into existence serve to prompt and direct their movements. What is commonly designated as the 'brain' of Invertebrata (more properly their 'cephalic ganglia') cannot be shown to consist of anything else than an assemblage of *sensorial* centres; and its actions appear to be entirely of a 'reflex' character, such of the movements of these animals as are not excito-motor, being performed (there is strong reason to believe) in direct respondence to sensations excited by internal or external impressions. Such movements, therefore, may be designated as *sensori-motor*, or *consensual*. Like the preceding, they do not appear to involve the participation either of Emotion, Reason, or Will; and the proportion which they bear to the actions of the excito-motor kind, seems to correspond pretty closely with the relative development of the cephalic ganglia and of the rest of the nervous system, as is very obvious when the larva and imago states of Insects are compared.—However disjointed the various 'excito-motor' centres may be amongst each other, we uniformly find them connected with the 'sensory' ganglia by commissural tracts; and this anatomical fact, with many phenomena which observation and experiment upon their actions have brought to light, makes it apparent, that besides the reflex actions which are performed through their own direct instrumentality, the sensory ganglia have a participation in those performed through other ganglionic centres. Thus it seems probable that a stimulus transmitted downwards from the sensory ganglia, to one of the ganglia of the trunk of a Centipede, excites the efferent nerves of that ganglion to call into contraction the muscles supplied by them, just as the excitor influence arriving at that ganglion through its own afferent nerves would do.

459. The whole Nervous System of Invertebrated animals, then, may be regarded as ministering entirely to *purely-reflex* action; and its highest development, as in the class of Insects, is coincident with the highest manifestations of the 'instinctive' powers, which, when carefully examined, are found to consist entirely in movements of the excito-motor and sensori-motor kinds. When we attentively consider the habits of these animals, we find that their actions, though evidently adapted to the attainment of certain ends, are very far from evincing a *designed* adaptation on the part of the beings that perform them, such as that of which we are ourselves conscious in our own voluntary movements, or which we trace in the operations of the more intelligent Vertebrata. For, in the first place, these actions are invariably performed in the same manner by all the individuals of a species, when the conditions are

the same; and thus are obviously to be attributed rather to a uniform impulse, than to a free choice, the most remarkable examples of this being furnished by the economy of Bees, Wasps, and other "social" Insects, in which every individual of the community performs its appropriate part, with the exactitude and method of a perfect machine. The very perfection of the adaptation, again, is often of itself a sufficient evidence of the unreasoning character of the beings which perform the work, for, if we attribute it to their own intelligence, we must admit that this intelligence frequently equals, if it does not surpass, that of the most accomplished Human reasoner.* Moreover, these operations are performed without any guidance from experience, for it can be proved in many cases, that it is impossible for the beings which execute them to have received any instruction whatever; and we see that they do not themselves make any progressive attempts towards perfection, but that they accomplish their work as well when they first apply themselves to it, as after any number of repetitions of the same acts. It is interesting to observe, moreover, that as these instinctive operations vary at different periods of life, so there is a corresponding variation in the structure of the Nervous system. Thus we see that, in the *larva* of the Insect, the operations are entirely directed towards the acquisition of food, and its organs of sense and locomotive powers are only so far developed as to serve this purpose. But in the *imago* or perfect Insect, the primary object is the continuance of the race: and the sensorial and motor endowments are adapted to enable the individual to seek its mate, and to make preparations (frequently of a most elaborate kind) for the nurture of the offspring.—Hence we can scarcely fail to arrive at the conclusion that the *adaptiveness* of the instinctive operations of Insects, &c., lies in the original construction of their nervous system, which causes particular movements to be executed in direct respondence to certain impressions and sensations. And this view is confirmed by the comparison of such movements with those which, in the Human subject, are most directly concerned in the maintenance of the life of the individual, and in the perpetuation of the race. For we have the evidence of our own consciousness in regard to these, that, however obvious their *purpose* may be, and however complete their *adaptation* to that purpose, they are performed, *not* with any notion of that purpose, but at the prompting of an irresistible impulse, which is not only independent of all intelligent appreciation of the result, but may produce its effect without even affecting the consciousness of the agent. Thus the infant seeks the nipple, and puts its muscles into suctorial action, without any knowledge, derived from experience, that by so doing it will relieve the uneasy feeling of hunger; and if we could imagine a man coming into the world with the full possession of all his faculties, we may feel tolerably certain that he would not wait to eat until he had learned by experience his dependence upon food. We shall see (§ 529) that adult animals whose Cerebral hemispheres have been removed, will eat food that is put into their mouths, although they will not go to seek it; and this is the case with many Human idiots. When the functions of the Brain are disturbed, or in partial abeyance, as in fever, we often observe a remarkable

* See "Princ. of Comp. Phys.," 4th edit., p. 694

return to the instinctive propensities in regard to food; and the Physician frequently derives important guidance with respect to the patient's diet and regimen (particularly as to the administration of wine), from the inclination or disinclination which he manifests. So, in regard to the intercourse of the sexes, the impulse which prompts to it does not arise from a knowledge of the ultimate purposes which it is designed to answer; and the higher powers of the mind are only so far concerned in it, that when the action of the instinctive impulse has led to the formation of a definite idea of the object of desire, the Intelligence is prompted to take means for its gratification.*

460. Thus, then, the type of psychical perfection among Invertebrated animals, which is manifested in the highest degree in the Social Insects, consists in the exclusive development of the Instinctive faculty; that is, of *automatic* powers of a very simple kind, in virtue of which, each individual performs those actions to which it is directly prompted by the impulses arising out of impressions made upon its afferent nerves, without any self-control or self-direction; so that it must be regarded as entirely a creature of necessity, performing its instrumental part in the economy of Nature from no design or will of its own, but in accordance with the plan originally devised by its Creator.

461. On turning to the Vertebrated series, on the other hand, we find that *its* type of psychical perfection—as shown in Man—consists in the highest development of the *Reason*, and in the supreme domination of the *Will*, to which all the 'automatic' actions, save those which are absolutely essential to the maintenance of the Organic functions, are brought under subjection: so that each individual becomes not only a thinking and reflecting, but a self-moving and self-controlling agent, whose actions are performed with a definite purpose which is distinctly before his own view, and are adapted to the attainment of their end by his own intelligence. This, however, is only true of Man in his most elevated state; and not only in ascending the Vertebrated scale, but also in watching the progressive evolution of *his* mental faculties during the earlier periods of his life, may we trace a regular gradation, from a condition but little (if at all) in advance of that of the higher Invertebrata, up to that which is displayed in the noblest examples of Humanity. Through the entire series, however, we perceive that the Excito-motor and Sensori-motor portion of the Nervous system (§ 464) constitutes its fundamental and essential part, serving not merely as the instrument whereby those actions are performed, which are as necessary among the higher animals as they are among the lower, for the maintenance of the Organic functions (§§ 24, 25), but also as the immediate recipient of all those impressions from without, by which the higher operations of Mind are excited, and as the executant of the actions which proceed from them. But as we

* We have not, perhaps, any right to affirm that there is *nothing whatever* analogous in the Invertebrata to the Reasoning powers and Will of higher animals; but if these faculties have any existence among them, they must be regarded as in a merely rudimentary state, corresponding with the undeveloped condition of the Cerebrum. The only distinct indication of intelligence displayed by Invertebrata, is the slight degree of capacity of "learning by experience" which some of them display; this capacity being limited to the mere formation of *associations* between the psychical states called up by different objects of sense, which we observe to be the first stage in the development of the mental powers in the Human infant. (See "PRINC. OF COMP. PHYS.," § 682 *note*).

ascend the Vertebrated scale, or as we watch the progressive psychical development of the Infant, we find it becoming more and more apparent that the actions are prompted, not so much by simple sensations as by ideas or notions of the objects to which they relate; these ideas being formed, in a large proportion of instances, upon the results of past experience and the course of action being shaped in accordance with it. In the acts of animals of a still higher grade, as in those of the Child, we can scarcely fail to perceive the manifestation of *reasoning processes* analogous to those which we ourselves perform, and the expressions of some of those *emotional states* of which we are ourselves conscious. The superaddition of these more elevated endowments, in the Vertebrated series, is coincident with the addition of a peculiar ganglionic centre, the *Cerebrum*, to the Sensori-motor apparatus; and the relative proportion which the former bears to the latter, both as to size and to complexity of structure, corresponds so closely with the degree of predominance which the Intelligence possesses over the Instinctive propensities, that it is scarcely possible to doubt that the Cerebrum is the instrument through which this higher form of psychical power is exercised. Much of this exercise, however, may still be *automatic* in its nature; for so long as the current of thought and feeling flows on in accordance with the direct promptings of Suggestion, and without any interference from Volition, may it be considered as a manifestation of the 'reflex' activity of the Cerebrum, which takes the form of a *mental instinct*. This reflex activity manifests itself not only in the psychical operations themselves, but also in muscular movements; and these, when they proceed from simple ideas without any excitement of feeling, may be designated as *ideo-motor*; whilst, if they spring from a passion or emotion, they are termed *emotional*. The *mental* instincts, however, are by no means as invariable in the different individuals of the same species, as are what may be termed the *physical* Instincts of that inferior part of the nervous apparatus, which is more closely connected with the maintenance of the Organic life, the particular changes which any given suggestions will excite in each, being partly determined by original constitution, and partly by acquired habits.

462. The superiority of the Mind of Man over that of the most elevated among the lower animals, consists, not only in the far greater variety and range of his faculties, but, yet more, in that dominant power of the Will, which enables him to utilize them with the highest effect. In so far as the course of his thoughts and feelings is the mere result of the action of external impressions upon an organization having certain respondent tendencies, must he be considered as irresponsible for his actions, his character being formed *for* instead of *by* him; but in so far as he can exert a Volitional power of directing his thoughts and controlling his feelings, may he rise superior to circumstances, make the most advantageous use of the Intellectual faculties with which he may be endowed, and bring his Moral character more and more into accordance with the highest type which his nature may be capable of attaining in the present sphere of existence. Notwithstanding the evidences of rationality which many of the lower animals present, and the manifestations which they display of emotions that are similar to our own, there is no ground to believe that *they* have any such controlling power; on the contrary, all

observation seems to lead to the conclusion, that they are under the complete domination of the ideas and emotions by which they may be for the time possessed, and have no power either of repressing these by a forcible act of Will, or of turning the attention, by a like voluntary effort, into another channel. In this respect, then, their condition resembles that of the Dreamer, the Somnambule, or the Insane patient, in all of whom this voluntary control is suspended, and who (when their minds are susceptible of external impressions) may be so 'played upon' by the suggestion of ideas, that any respondent action consistent with the habitual mental state of the individual, may be evoked by an appropriate stimulus; just as we see in the case of animals that are trained to the performance of particular sets of movements, which are executed in respondence to certain promptings conveyed to them through their sensorium. Now between the complete want of this controlling power of the Will, and the most perfect possession of it, every intermediate gradation is presented by the several individuals which make up the Human species, some persons being so much accustomed, in consequence of the weakness of their Will, to act directly upon the prompting of every transient impulse, that they can scarcely be said to be voluntary agents; and others allowing certain *dominant* ideas or *habitual* feelings to gain such a mastery over them, as to exercise that determining power which the Will alone ought to exert. This gradation may be perfectly traced in children, in whose education the development of the faculty of 'self-control' should be a leading object; and it is also displayed in certain phases of mental Imbecility, which result from a deficiency of the power of voluntarily fixing the attention upon any object of consciousness, and of thus withdrawing it either from external objects that tend to distract the mind, or from notions it has adopted which hold it in subjection.

463. When we apply ourselves to the study of the Cerebro-Spinal Nervous centres of Man, we find ourselves peculiarly liable to be misled by the great development which the Cerebrum presents, both as to size and to complexity of structure, in proportion to the other centres; and thus it has happened that, through the too exclusive attention commonly paid to *Human* Anatomy, the meaning of the facts brought to light by dissection has been very commonly misapprehended, and many of the physiological interpretations based upon them have been completely negatived by more extended inquiry.—It is only, in fact, by studying the Cerebro-Spinal apparatus in its lowest, as well as in its highest form, and by bringing the intervening grades into comparison with both extremes, that it is possible to establish what are its fundamental or essential, and what its accessory parts; and in this way only can such a correspondence be established, between the development of a particular structure, and the manifestation of a psychical endowment, as may enable the latter to be attributed with any degree of probability to the former. In fact there is no part of the Human Organism, as to which the advantages of such a comparison are so striking, or in which the value of the "experiments ready prepared for us by Nature" is so much above that of the results of artificial mutilations.

464. *Cerebro-Spinal Nervous Centres.*—Under the guidance, then, of these principles, we find that we may distinguish, as the fundamental part of the Cerebro-Spinal apparatus of Man, the *Cranio-Spinal Axis*,

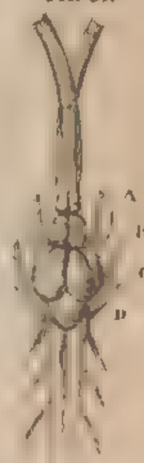
consisting of the Spinal Cord, the Medulla Oblongata, and the Sensory Ganglia, and altogether constituting the centre of automatic movement. —The Spinal Cord, consisting of a tract of vesicular matter enclosed within strands of longitudinal fibres, and giving-off successive pairs of intervertebral nerves which are connected at their roots with both of these components, is obviously homologous with the ganglionated ventral column of the Articulata, chiefly differing from it in the continuity of the ganglionic substance which occupies its interior; and each segmental division of it, which serves as the centre for its own pair of nerves, may be considered, like each ganglion of the ventral column of the Articulata, as a repetition of the single 'pedal' or locomotive ganglion of the Mollusca.—The Medulla Oblongata consists of a set of strands which essentially correspond with the cords that pass round the œsophagus in Invertebrated animals, connecting the cephalic ganglia with the first sub-œsophageal ganglion; but as the whole cranio-spinal axis in the Vertebrata lies *above* the alimentary canal (the trunk being supposed to be in a horizontal position), there is no such divergence of these strands, the only separation between them being that which is known as the 'fourth ventricle.' Interposed among the commissural fibres of the Medulla Oblongata, however, are certain collections of vesicular matter, which serve as the ganglionic centres for the movements of respiration and deglutition, and which thus correspond with the respiratory and stomato-gastric ganglia of Invertebrated animals. This incorporation of so many distinct centres into one system, would seem destined in part to afford to all of them the protection of the vertebral column, and in part to secure that consentaneousness of action and that ready means of mutual influence, which are peculiarly requisite in beings in which the activity of the Nervous system is so predominant. Thus the close connection which is established in the higher Vertebrated animals, between the respiratory and the general locomotive apparatus, is obviously subservient to the use which the former makes of the latter in the performance of its functions; whilst, on the other hand, the control which the encephalic centres possess over the actions of the respiratory ganglia enables the will to regulate the inspiratory and expiratory movements in the manner required for the acts of vocalization.—Under the term Sensory Ganglia, may be comprehended that assemblage of ganglionic masses lying along the base of the skull in Man, and partly included in the Medulla Oblongata, in which the nerves of the 'special senses,' Taste, Hearing, Sight, and Smell, have their central terminations; and with these may probably be associated the two pairs of ganglionic bodies known as the Corpora Striata and Thalami Optici, into which may be traced the greater proportion of the fibres that constitute the various strands of the Medulla Oblongata, and which seem to stand in the same kind of relation to the nerves of Touch or 'common sensation,' that the Olfactive, Optic, Auditory, and Gustative ganglia bear to *their* several nerve-trunks.

465. Now it is not a little interesting, that this Cranio-Spinal axis, which represents in Vertebrated animals the whole nervous system of the Invertebrata (with the exception of the rudiment of the Sympathetic which they possess), should exist in the lowest known Vertebrated animal without any superaddition, and should be sufficient for the per-

formance of all its actions. Such is the case in the curious *Amphioxus*, a little fish which presents not the slightest trace of either Cerebrum or Cerebellum, and in which even the sensory ganglia and the organs of special sense have only a rudimentary existence; and, in which, too, the spinal cord is composed of a series of ganglia that are obviously distinct from each other, although in close approximation. And even in the lower Cyclostome Fishes, the condition of the nervous centres is very little above this, save as regards the larger development of the sensory ganglia. This condition has its parallel, even in the Human species, in the case of Infants which are occasionally born without either Cerebrum or Cerebellum; such have existed for several hours, or even days, breathing, sucking, crying, and performing various other movements; and there is no physiological reason why their lives should not be prolonged, if they be nurtured with sufficient care (§ 25).

466. In Man, however, as in all the higher Vertebrata, we find superimposed (as it were) upon the Sensory ganglia, and constituting the principal mass of the Encephalon, the bodies which are known as the *Cerebral Hemispheres*, or *Hemispheric Ganglia*. Now when these are so greatly developed, as to cover-in and obscure the Sensory ganglia to the degree which presents itself in Man, it is not surprising that the fundamental importance of the latter should not be generally recognized; in Fishes, however, the proportion between the two sets of centres is entirely reversed, the rudiments of the Cerebral Hemispheres (Fig 80, B) being usually inferior in size to the Optic ganglia (C) alone. Indeed, of the pair of ganglionic masses to which that designation is usually applied, it may be almost positively stated, that the greater part is homologous with the Corpora Striata of the Human brain, it being only in the higher Cartilaginous fishes, that a ventricular cavity exists in each of these bodies, separating the thin layer of true Cerebral substance which overlies it, from the ganglionic mass which forms its floor. Between these two extremes, a regular gradation is presented in the intermediate tribes.—Now it is a point especially worthy of note, that no sensory nerves terminate directly in the Cerebrum, nor do any motor nerves issue from it, and there seems a strong probability that there is *not* (as formerly supposed) a direct continuity between even all or any of the nerve-fibres distributed to the body, and the medullary substance of the Cerebrum. For whilst the nerves of 'special' sense have their own ganglionic centres, it cannot be shown that the nervous fibres of 'general' sense, which either enter the cranium as part of the cephalic nerves, or which pass-up from the Spinal cord, have any higher destination than the Thalami Optici (§ 519). So the motor fibres which pass-forth from the cranium, either into the cephalic nerve-trunks, or into the motor columns of the Spinal cord, though commonly designated as *Cerebral*, cannot be certainly said to have a higher origin than the Corpora

Fig. 80.



Brain of Cod,—A, olfactive ganglia; B, cerebral lobes; C, optic ganglia; D, cerebellum

Striata. And we shall find strong physiological as well as anatomical ground for the belief, that the Cerebrum has no communication with the external world, otherwise than by its connection with the Sensori-motor apparatus; and that even the movements which are usually designated as 'voluntary' are only so as regards their original source, the stimulus which calls the muscles into contraction being even then that which is issued from the Cranio-Spinal axis, as it is in the movements prompted by the reflex stimulation of an external impression.

467. Wherever a Cerebrum is superimposed upon the Sensory Ganglia, we find another ganglionic mass, the *Cerebellum*, superimposed upon the Medulla Oblongata. The development of this organ bears a general, but by no means a constant relation to that of the Cerebrum; for in the lowest Fishes it is a thin lamina of nervous matter on the median line, only partially covering-in the 'fourth ventricle,' whilst in the higher Mammalia, as in Man, it is a mass of considerable size, having two lateral lobes or hemispheres in addition to its central portion. The direct communication which the Cerebellum has with both columns of the Spinal cord, and the comparatively slight commissural connection which it possesses with the higher portions of the Encephalic centres, justify the supposition that it is rather concerned in the regulation and co-ordination of the actions of the former, than in any proper psychical operations; and it will hereafter be shown that the various kinds of evidence afforded by Comparative Anatomy, by Experimental inquiry, and by Pathological observation, all tend to support this view of its function.

468. Now although every segment of the Spinal Cord, and every one of the Sensory Ganglia, may be considered, in common with the Cerebrum, as a true and independent centre of nervous power, yet this independence is only manifested when these organs are separated from each other; either structurally—by actual division; or functionally—by the suspension of the activity of other parts. In their state of perfect integrity and complete functional activity, they are all (at least in Man) in such subordination to the Cerebrum, that they only minister to its actions, except in so far as they are subservient to the maintenance of the Organic functions, as in the automatic acts of breathing and swallowing. With regard to every other action, the Will, if it possess its due predominance, can exercise a determining power; keeping in check every automatic impulse, and repressing the promptings of emotional excitement. And this seems to result from the peculiar arrangement of the nervous apparatus; which causes the excitor *impression* to travel in the *upward* direction, if it meet with no interruption, until it reaches the Cerebrum, without exciting any reflex movements in its course. When it arrives at the Sensorium, it makes an impression on the consciousness of the individual, and thus gives rise to a *sensation;* and the change thus induced, being further propagated from the sensory ganglia to the Cerebrum, becomes the occasion of the formation of an *idea*. If with this idea any pleasurable or painful feeling should be associated, it assumes the character of an *emotion*, and either as a simple or as an emotional idea, it becomes the subject of *intellectual operations* whose final issue is in a *volitional determination*, or act of the Will, which may be exerted in producing or checking a muscular movement, or in controlling or directing the current of thought.

apparatus of Organic life, the *Visceral* system. To this system we are probably to refer, not only the Semilunar and Cardiac ganglia (which seem to be its principal centres), with the chain of cranial, cervical, thoracic, lumbar, and sacral ganglia, which are in nearer connection with the Cerebro spinal system; but also numerous minute ganglia, which are to be found on its branches in various parts. Moreover, the ganglia upon the posterior roots of the Spinal nerves, and those upon the roots and trunks of certain Cranial nerves, may be ranked with considerable probability under the same category; and if such be the case, those fibres contained in the cerebro-spinal nerves, which have these as their ganglionic centres, must also be accounted as belonging to the Sympathetic system. On the other hand, there unquestionably exist numerous fibres in the Visceral system, which proceed into it from the Cerebro-spinal system; these, however, are not uniformly distributed, for some of the Visceral nerves contain few or none of them, whilst in others they are numerous. The branches by which the Sympathetic system communicates with the Cerebro-spinal, and which were formerly considered as the *roots* of the Sympathetic system, seem to contain fibres of both kinds, *i.e.*, Cerebro-spinal fibres passing into the Sympathetic, and Sympathetic fibres passing into the Cerebro-spinal. The latter are chiefly, if not entirely, transmitted into the *anterior* branches of the Spinal nerves; the *posterior* branches being apparently supplied with sympathetic fibres from the ganglia on their own posterior roots. Some of these last fibres also pass from the Cerebro-spinal into the Sympathetic system. By these communications, the two systems of fibres are so blended with each other, that it is impossible to isolate them.—The branches proceeding from the Semilunar ganglia are distributed upon the abdominal viscera; and those of the Cardiac ganglia upon the heart and the vessels proceeding from it. The latter seem to accompany the arterial trunks through their whole course, ramifying minutely upon their surface; and it can scarcely be doubted that they exercise an important influence over their functions. What the nature of that influence may be, however, will be a subject for future inquiry (CHAP. XV.). It is so evidently connected with the operations of nutrition, secretion, &c., that the designation 'nervous system of organic life,' as applied to this system, does not seem objectionable, provided that we do not understand it as denoting the *dependence* of these functions upon it.—The inter-penetration of the Cerebro-spinal system by the Sympathetic, is strongly marked by these two circumstances;—that, in some of the lower Vertebrata, the distribution of their trunks cannot be separately distinguished;—and that, even in the highest, some of the glands, of which the secretion is most directly influenced by the condition of the mind, are supplied with most of their nerves from the cerebro-spinal system, the lachrymal and sublingual glands receiving large branches from the fifth pair, and the mammary glands from the intercostal nerves.

472. *Cerebro-Spinal Nerve-Trunks.*—Having thus considered the principal attributes of the ganglionic centres of the Cerebro-Spinal system, we have next to inquire into those of the nerve-trunks which are connected with them. It is only in the Vertebrata, that the difference between the *afferent* and *efferent* fibres of the nerves has

been satisfactorily determined. The merit of this discovery is almost entirely due to Sir C. Bell, who has led to it by a chain of reasoning of a highly philosophical character; and although his first experiments on the Spinal nerves were not satisfactory, he virtually determined the respective functions of their two roots,—the posterior as *sensory* (afferent), the anterior as *motor* (efferent),—by experiments and pathological observations upon the Cranial nerves, some of which contain only one class of fibres to the exclusion of the other, before any other physiologist came into the field.* Subsequently his general views were confirmed by the very decided experiments of Muller; but until very recently, some obscurity hung over a portion of the phenomena. It was from the first maintained by Magendie, and has been subsequently asserted by other physiologists, that the posterior and anterior roots of the nerves were *both* concerned in the reception of impressions and in the production of motions; for that, on touching the posterior roots, not only the sensibility of the animal seemed to be affected, but muscular motions were excited: and that, when the anterior roots were touched, the animal gave signs of pain, at the same time that convulsive movements were performed. These physiologists were not willing, therefore, to admit more, than that the posterior roots were *especially* sensory, and the anterior *especially* motor. But the knowledge we now possess of the 'reflex function' of the Spinal Cord, enables the former portion of these phenomena to be easily explained. The motions excited by irritating the posterior roots, are found to be entirely dependent upon their connection with the Spinal Cord, and upon the integrity of the anterior roots and of the trunks into which they enter; whilst they are not checked by the separation of the posterior roots from the peripheral portion of the trunk. It is evident, therefore, that excitation of the posterior roots does not act immediately upon the muscles, through the trunk of the nerve which they contribute to form; but that it excites a reflex motor impulse in the Spinal Cord, which is propagated through the anterior roots to the periphery of the system. The converse phenomenon, the apparent sensibility of the anterior roots, has been explained by the experiments of Dr. Kronenberg,† which seem to prove that it is dependent upon a branch from the posterior roots, passing into the anterior roots at their point of inosculation, and then directing itself towards the cord (§ 477).

473. Every fibre, there is reason to believe, runs a distinct course between the central organ, in which it loses itself at one extremity, and the organ of sense, muscle, or other tissue, in which it terminates at the other; in the terminal ramifications of the nerves, however, a *subdivision* of the fibres is frequently observable. Each nervous trunk is made up of several fasciculi of these fibres, and each fasciculus is composed of a large number of the ultimate fibres themselves. Although the fasciculi occasionally intermix and exchange fibres with one another (as occurs in a *plexus*), the fibres themselves never inosculate. Each fibre would seem, therefore, to have its appropriate office, which it cannot share with another.—Several objects appear to be attained by the plexiform arrangement. In some instances it serves to intermix fibres, which have endowments fundamentally different: for example, the Spinal Accessory nerve,

* See "Brit. and Foreign Med. Review," vol. ix. p. 140, &c.
† "Muller's Archiv.," 1839, Heft v., and "Brit. and For. Med. Rev.," vol. ix. p. 547

at its origin, appears to be exclusively motor, and the roots of the Pneumogastric to be exclusively afferent; but by the early admixture of these, a large number of motor fibres are imparted to the Pneumogastric, and are distributed in variable proportion, with its different branches; whilst a few of its sensory filaments seem to enter the Spinal Accessory.—In other instances, the object of a plexus appears to be, to give a more advantageous distribution to fibres, which all possess corresponding endowments. Thus the Brachial plexus mixes-together the fibres arising from five segments of the spinal cord, and sends off five principal trunks to supply the arm. Now if each of these trunks had arisen by itself, from a distinct segment of the spinal cord, so that the parts on which it is distributed had only a single connection with the nervous centres, they would have been much more liable to paralysis than at present. By means of the plexus, every part is supplied with fibres arising from each segment of the spinal cord; and the functions of the whole must therefore be suspended, before complete paralysis of any part can occur from a cause which operates above the plexus. Such a view is borne-out by direct experiment; for it has been ascertained by Panizza that, in Frogs, whose Crural plexus is much less complicated than that of Mammalia, section of the roots of one of the three nerves which enter into it, produces little effect on the general movements of the limb; and that, even when two are divided, there is no paralysis of any of its actions, all being weakened in a nearly similar degree.—But as Dr. Gull has pointed out,* one use of such a plexus as the brachial or the crural appears to be, to bring the muscles which derive their nervous supply from it, into relation with different ganglionic segments of the Spinal Cord; each of which may exert a diverse action, either in virtue of its own endowments, or of the influence of the will upon it; so that groups of muscles may thus be associated for combined actions. All consideration of the mode in which we make use of our muscles, and of the power which we have over them, leads to the conclusion that each ganglionic centre has a specific and limited sphere of influence, producing certain movements and no others; hence, for the execution of a variety of movements in harmonious combination with each other, it seems requisite that the nervous supply of each muscle should be derived from several different centres; and thus it is, that the complication of plexuses comes to be related to the variety of movements of the parts supplied through them.—It is not a little interesting to remark, that arrangements of a similar kind should present themselves among the higher Invertebrata (PRINC. OF COMP. PHYS., §§ 646, 657).

474. The following statements, in which the doctrines of Prof. Müller† are adopted with some modifications and additions, embody the general principles ascertained by experiment, respecting the transmission of Sensory and Motor impressions along the nerves which respectively minister to them. Their *rationale* will be at once understood, from the facts already mentioned in regard to the isolated character of each fibril, and the identity of its endowments through its whole course.

I. When the whole trunk of a *sensory* nerve is irritated, a sensation is produced, which is referred by the mind to the parts to which its branches

* 'Gulstonian Lectures on the Nervous System,' in "Medical Times," 1849, p. 372.
† "Elements of Physiology," translated by Dr. Baly; pp. 680, 686

are ultimately distributed; and if only part of the trunk be irritated, the sensation will be referred to those parts only, which are supplied by the fibrils it contains.—This is evidently caused by the production of a change in the sensorium, corresponding with that which would have been transmitted from the peripheral organs of the nerves, had the impression been made upon them (§ 599). Such a change only requires the integrity of the afferent trunk between the point irritated and the sensorium, and is not at all dependent upon the state of the peripheral part to which the sensations are referred; for this may have been paralysed by the division or other lesion of the nerve, or may have been altogether separated as in amputation, or the relative position of its parts may have been changed, as in autoplastic operations. So, when different parts of the thickness of the same trunk are separately and successively irritated, the sensations are successively referred to the several parts supplied by these divisions. This may be easily shown by compressing the ulnar nerve in different directions, where it passes at the inner side of the elbow joint. Still the mind undoubtedly does possess a certain power of discriminating the part of the nerve-trunk on which the impression is made; for when the impression is such as to produce sensations that are referred to its peripheral extremities, pain is at the same time felt in the spot itself; and it would seem as if slight impressions are *only* felt in the latter situation, at least in the normal condition of the trunk or fibre. Thus, as it has been well remarked by Volkmann, "if a needle's point be drawn in a straight line across the back, or the thigh, or any part in which the nerves are widely placed, the mind perceives the line of irritation as a straight one; whereas, if it referred all impressions to the ends of the fibres, this mode of irritation should be felt in sensations variously scattered about the line, at the points where the nerve-fibres crossed by the needle terminate."*

II. The sensation produced by irritation of a branch of the nerve, is confined to the parts to which that branch is distributed, and does not affect the branches which come-off from the nerve higher up. The rationale of this law is at once intelligible; but it should be mentioned that there are certain conditions, in which the irritation of a single nerve will give rise to sensations over a great extent of the body. This 'radiation of sensations' seems rather due, however, to a particular state of the *central* organs, than to any direct communication among the peripheral fibres.

III. The *motor* influence is propagated only in a centrifugal direction, never in a retrograde course. It may originate in a spontaneous change in the central organs, or it may be excited by an impression conveyed to them through afferent nerves; but in both cases its law is the same.

IV. When the whole trunk of a motor nerve is irritated, all the muscles which it supplies are caused to contract. This contraction evidently results from the similarity between the effect of an artificial stimulus applied to the trunk in its course, and that of the change in the central

* "Kirkes and Paget's Handbook of Physiology," p. 575. It does not seem [illegible] however, that in the case of the compression or other irritation of a large nerve-trunk [illegible] [illegible] *nervi nervorum*, [illegible] than the [illegible]

organs by which the motor influence is ordinarily propagated. But when only a part of the trunk or a branch is irritated, the contraction is usually confined to the muscles which receive their nervous fibres from it; in this instance, as in the other, there is no lateral communication between the fibrils.—An exception exists, however, in regard to galvanic irritation, which may be transmitted laterally when its ordinary course is checked; as has been shown by the following ingenious experiment of M. du Bois-Reymond. If any motor nerve be selected which divaricates into two branches (as, for example, the sciatic nerve of a frog, which divides above the bend of the knee into the tibial and peroneal branches), and a galvanic stimulus be applied to either of these branches, this having been first divided above its insertion into the muscles, the electrotonic state will be developed, not merely in the portion of the trunk continuous with that branch, but also in that which is continuous with the other branch, as will be made apparent by the contraction in the muscles supplied by the latter. That this experiment may be free from the possible fallacy resulting from the excitement of reflex action, the trunk of the sciatic nerve should be divided high-up, or the spinal cord be destroyed.

475. *Determination of the Functions of Nerves.*—Various methods of determining the functions of particular nerves present themselves to the Physiological inquirer. One source of evidence is drawn from their *peripheral distribution.* For example, if a nervous trunk is found to lose itself entirely in the substance of Muscles, it may be inferred to be chiefly, if not entirely, *motor* or *efferent.* In this manner, Willis long ago determined that the Third, Fourth, Sixth, Portio dura of the Seventh, and Ninth cranial nerves, are almost entirely subservient to muscular movement; and the same had been observed of the fibres proceeding from the small root of the Fifth pair, before Sir C. Bell experimentally determined the double function of that division of the nerve into which alone it enters. Again, where a nerve passes through the muscles, with little or no ramification among them, and proceeds to a Cutaneous or Mucous surface, on which its branches are minutely distributed, there is equal reason to believe that it is of a *sensory*, or rather of an *afferent*, character. In this manner Willis came to the conclusion, that the Fifth pair of cranial nerves differs from those previously mentioned, in being partly sensory. Further, where a nerve is *entirely* distributed upon a surface adapted to receive impressions of a *special* kind, as the Schneiderian membrane, the retina, or the membrane lining the internal ear, it may be inferred that it is not capable of transmitting any other kind of impressions, for experiment has shown that the *special sensory* nerves do not possess common sensibility. The case is different, however, in regard to the sense of taste, which originates in impressions not far removed from those of ordinary touch; and it is probable that the same nerves minister to both.—Anatomical evidence of this kind is valuable also, not only in reference to the functions of a principal trunk, but even as to those of its several branches, which, in some instances, differ considerably. Thus, some of the branches of the Pneumogastric are especially motor, and others almost exclusively afferent; and anatomical examination, carefully prosecuted, not only assigns the reasons for these functions, when ascertained, but is in itself nearly sufficient to determine

them. For the superior laryngeal branch is distributed almost entirely upon the mucous surface of the larynx, the only muscle it supplies being the crico-thyroid; whilst the inferior laryngeal or recurrent is almost exclusively distributed to the muscles. From this we might infer that the former is an afferent, and the latter a motor nerve; and experimental inquiries (as we have seen, § 304) fully confirm this view. In like manner it may be shown, that the Glosso-pharyngeal is chiefly an afferent nerve, since it is distributed to the *surface* of the tongue and pharynx, and scarcely at all to the muscles of those parts, whilst the pharyngeal branches of the Pneumogastric are chiefly, if not entirely, motor (§ [illegible]). Lower down, however, the branches of the Glosso-pharyngeal cease, and the œsophageal branches of the Pneumogastric are distributed both to the mucous surface and to the muscles, from which it may be inferred that they are both afferent and motor; a deduction which experiment confirms (§ 82).—We perceive, therefore, that much knowledge of the function of a nerve may be obtained, from the attentive study of its ultimate distribution; but it is necessary that this should be very carefully ascertained, before it is made to serve as the foundation for physiological inferences. As an example of former errors in this respect, may be mentioned the description of the Portio dura of the Seventh pair given by Sir C. Bell; for he incorrectly stated it to be distributed to the skin as well as to the muscles of the face, and erroneously regarded it as in part an afferent nerve, subservient to respiratory impressions as well as to motions. In the same manner, from inaccurate observation of the ultimate distribution of the Superior Laryngeal nerve, it was long regarded as that which stimulated to action the constrictors of the glottis.

476. But the knowledge obtained by such anatomical examinations alone is of a very general kind; and requires to be made particular,—to be corrected and modified,—by other sources of information. One of these relates to the *connexion of the trunks with the central organs.* The evidence derived from this source, however, is seldom of a very definite character; and, in fact, Physiologists have rather been accustomed to judge of the functions of particular divisions of the nervous centres by those of the nerves with which they are connected, than to draw aid from the former in the determination of the latter. Still, this kind of examination is not without its use, when there is reason to believe that a particular tract of fibrous structure has a certain function, and when the office of a nerve whose roots terminate in it is doubtful. Here, again, however, very minute and accurate examination is necessary, before any sound physiological inferences can be drawn from facts of this description; and many instances might be adduced to show, that the real connexions of nerves and nervous centres are often very different from their apparent ones.

477. Most important information as to the functions of particular nerves may be drawn from *experimental inquiries;* but these also are liable to give fallacious results, unless they are prosecuted with a full knowledge of all the precautions necessary to insure success. Some of these will be here explained. In the first place, the endowments of the *trunk* and of the *roots* of a nerve may differ; owing to the admixture in the former, of fibres derived by inosculation from another nerve (§ [illegible]).

Hence, in order to attain satisfactory results, a comparative set of experiments should always be made upon each. —A nerve-trunk may be too hastily considered as *motor*, on account of the excitation of muscular movements by irritation of its trunk, whilst still in connection with its centre; for such movements may be called-forth, not only by the direct influence of the nerve upon the muscles, but also by reflex stimulation, acting through the ganglionic centre upon some other nerve. The real nature of such movements can only be determined by dividing the trunk, and then irritating each of the cut extremities. If, upon irritating the end *separated* from the centre, muscular contractions are produced, it may be safely inferred that the nerve is, in part at least, of an *efferent* character. Should no such result follow, this would be improbable. If, on the other hand, muscular movement should be produced by irritating the extremity *in connexion with* the centre, it will then be evident, that it is occasioned by an impression conveyed *towards* the centre by *this* trunk, and propagated to the muscles by some other; in other words, to use the language of Dr. M. Hall, this nerve is an 'excitor' of motion, not a direct motor nerve. The Glosso-pharyngeal has been satisfactorily determined, by experiments of this kind, performed by Dr. J. Reid (§ 81), to be chiefly, if not entirely, an afferent nerve. —It has been from the want of a proper mode of experimenting, that the functions of the *posterior* roots of the Spinal nerves have been regarded as in any degree motor. If they be irritated, without division of either root, motions are often excited; but if they be divided, and their separated trunks be then irritated, no motions ensue; nor are any movements produced by irritation of the roots in connexion with the spinal cord, if the *anterior* roots have been divided. Hence it appears that these fibres do not possess any direct motor powers, but that they convey impressions to the centre, which are reflected to the muscles through the anterior roots.—The same difficulties do not attend the determination of the *sensory* endowments of nerves. If, when the trunk of a nerve is pricked or pinched, the animal exhibit signs of pain, it may be concluded that the nerve is capable of receiving and transmitting sensory impressions from its peripheral extremity. But it happens not unfrequently, that this capability is derived by inosculation with another nerve; as is the case with the Facial, which is sensory after it has passed through the parotid gland, having received there a twig from the Fifth pair.* A similar inosculation explains the apparent sensibility of the *anterior* roots of the Spinal nerves. If these be irritated, the animal usually gives signs of uneasiness; but if they be divided, and the cut ends nearest the centre be irritated, none such are exhibited, whilst they are still shown when the farther ends are irritated, but not if the posterior roots are divided. This seems to indicate that, from the point of junction of the two roots, sensory fibres derived from the posterior roots pass backwards (or towards the centre) in the anterior; and that the apparent sensory endowments of the latter are entirely dependent upon their connexion with the posterior column of the spinal cord, through the posterior roots.

478. The fallacies to which all experiments upon the nerves are subject, arising from the partial loss of their power of receiving and conveying impressions, and of exciting the muscles to action, after death, are too obvious to require more particular mention here; yet they are frequently

* [illegible] seems to become sensitive in [illegible] of a twig from the [illegible]

overlooked. Of a similar description are those arising from severe disturbance of the system, in consequence of operations, which also have not been enough regarded by experimenters.—As a general rule, negative results are of less value than *positive*; but very careful discrimination is often required to determine what *are* negative, and what positive results. Each particular case has its own sources of fallacy, which require to be logically scrutinized, and the only satisfactory proof is derived from the concurrence of every kind of evidence, which the nature of the inquiry admits of. Thus in the determination of the functions of a particular nerve-trunk, it should be shown that a certain effect is *constantly* produced by its excitation (under the conditions laid-down in the preceding paragraph), and that a corresponding interruption in the action to which it is hence inferred to be subservient, takes place when its continuity has been interrupted: by this double proof, the Glosso-pharyngeal and the Pneumogastric are shown to be the principal, but not the sole, excitors of the movements of Deglutition and Inspiration respectively. But the evidence afforded solely by the interruption of a particular function after the division of a certain nerve, or the destruction or removal of a nervous centre, is by no means so satisfactory; for this may be occasioned rather by the general effects of the operation, than by the simple lesion of the nervous apparatus. In order to get rid, so far as possible, of this source of fallacy (which particularly affects experiments upon the Encephalic centres, and upon the influence of the nerves upon the viscera), it is desirable to perform comparative experiments, in which the general injury shall be as nearly as possible the same, and the only difference shall be in the lesion of the nervous system; and to subtract from the entire result all that can be thus shown to be attributable to the general disturbance produced by the operation. But even then, it may happen that the function is only suspended for a time, by the shock which has been induced by the injury to the nerve; and if it should be subsequently renewed, without any reunion of the trunk, we have the most convincing proof that, whatever degree of participation the nerve may have in it, the action is not essentially dependent upon the integrity of that portion of the nervous apparatus. Such we have seen to be the case, in regard to the relation of the Pneumogastric nerves to the secretion of gastric fluid in the walls of the stomach (§§ 101-103).

479. All our positive knowledge of the functions of the Nervous System in general, save that which results from our own consciousness of what passes within ourselves, and that which we obtain from watching the manifestations of disease in Man, is derived from observation of the phenomena exhibited by animals made the subjects of experiments; and in the interpretation of these, great caution must be exercised.—In the first place it must be constantly borne in mind, that, except through the *movements* consequent upon them, we have no means of ascertaining, whether or not particular changes in the Nervous System, whose character we are endeavouring to determine, are attended with Sensation; since we have no power of judging whether or not this has been excited, save by the cries and struggles of the animal made the subject of experiment. Now although such cries and struggles are ordinarily considered as indications of pain, yet it is not right so to regard them in every instance; and the only unequivocal evidence is derived from observation of the correspond-

ing phenomena in the Human subject; since we can there ascertain, by the direct testimony of the individual affected, what impressions produce sensation, and what excite movements independently of sensation (§§ 506-509). Further, we are not justified in assuming that Consciousness is excited by an irritation, still less that Intelligence and Will are called into exercise by it, merely because movements, evidently tending to get rid of its source, are performed in respondence to it. We know that the contractions of the heart and alimentary tube are ordinarily excited by a stimulus, without any sensation being involved; and these movements, like all that are concerned in the maintenance of the Organic functions, have an obvious *design*, when considered either in their immediate effects, or in their more remote consequences. The character of *adaptiveness*, then, in Muscular movements excited by external stimuli, is no proof that they are performed in obedience to sensation, much less that they have a voluntary character. In no case is this adaptiveness more remarkable, than in some of those actions, which are not only performed without any effort of the will, but which the will cannot imitate. This is the case, for example, with the act of Deglutition (§§ 81, 82), the muscles concerned in which cannot be thrown into contraction by a voluntary impulse, being stimulated only by impressions conveyed from the mucous surface of the fauces to the Medulla Oblongata, and thence reflected along the motor nerves. No one can swallow, without producing an impression of some kind upon this surface, to which the muscular movements will immediately respond. Now it is impossible to conceive any movements more perfectly adapted to a given purpose, than are those of the parts in question; and yet they are independent, not only of volition but of sensation, being still performed in cases, in which consciousness is completely suspended, or entirely absent. The act of Sucking in the infant, again, is one in which a number of muscles are called into combined contraction, in a manner which shows a complete adaptation to a given purpose; and yet it is impossible to suppose this adaptation to be *purposive* on the part of the infant itself; more especially as it is shown, both by the occurrence of monstrosities, and by experiments made with this object (§ 77), that no part of the Cranio-spinal axis above the Medulla Oblongata is necessary to it. And in the acts of Coughing and Sneezing (§ 506), we have additional examples of the most *adaptive* movements, executed by a marvellous combination of separate muscular actions, with the obvious purpose of removing sources of irritation from the air-passages; and yet we know by personal experience, that this combination is *not* made with any design of our own.

2. *Of the Spinal Cord and Medulla Oblongata;—their Structure and Actions.*

480. In our more detailed consideration of the functions of the several divisions of the Nervous System, it is desirable, for several reasons, to commence with the *Cranio-Spinal Axis*, which, as already pointed-out (§ 464), may be considered as constituting the fundamental portion of this apparatus. The entire Axis is divided into its Cranial and its Spinal portions, the passage of the Cord through the 'foramen magnum' of the occipital bone being considered to mark the boundary between them; and

although the separation of the Medulla Spinalis from the Medulla Oblongata, which is thus established, is in itself purely artificial, yet it will be found to correspond completely with the natural division founded on their respective physiological attributes.

481. The *Spinal Cord*,* which extends from the margin of the foramen magnum to the first or second lumbar vertebra, and which is prolonged as the *filum terminale*† to the extremity of the sacral canal, is almost completely divided by the *anterior* and *posterior median fissures* (Fig. 81, *a*, *p*),

Fig. 81.

Transverse section of *Human Spinal Cord*, through the middle of the lumbar enlargement, showing on the right side the course of the nerve-roots, and on the left the position of the principal tracts of vesicular matter:—A, A, anterior columns; P, P, posterior columns; C, C, lateral columns; *a*, anterior median fissure; *p*, posterior median fissure; *b*, *b*, *b*, *b*, anterior roots of spinal nerves; *c*, *c*, posterior roots; *d*, *d*, tracts of vesicular matter in anterior column; *e*, tracts of vesicular matter in posterior column; *f*, spinal column; *g*, substantia gelatinosa.

into two lateral and symmetrical halves. The 'anterior median fissure' (*a*) is more distinct than the posterior, being wider at the surface; but it only penetrates to about one-third of the thickness of the Cord, its depth increasing, however, towards its lower part. The sides of the 'posterior median fissure' (*p*), on the other hand, are in closer approximation; but the division commonly extends to about half the thickness of the cord, being deeper towards its upper than towards its lower end.

* The sketch given in the text of the Anatomy of the Spinal Cord, is chiefly derived from the statements of Prof. Kölliker in his "Mikroskopische Anatomie" (Band ii, §§ 115-116), and of Mr. J. L. Clarke in the "Philosophical Transactions," 1851 and 1853, between which there is a general accordance.

† The structure of the 'filum terminale' is in every respect essentially the same as that of the proper Spinal Cord, save that no nerve-roots are connected with it.

The two halves, therefore, are only united by a commissural band, which occupies the central part of the cord; and this is traversed by the 'Spinal canal' (*f*), which is continued downwards from the fourth ventricle.* At a little distance from either side of the posterior median fissure, and corresponding with the line of attachment of the posterior roots of the nerves, is the *posterior lateral furrow;* a shallow longitudinal depression, which marks-out the 'posterior columns' of the Cord (P, P) as distinct from the 'antero-lateral columns.' A corresponding furrow has been sometimes described as traversing the Cord in the line of the anterior roots of the nerves on either side; but this can scarcely be said to have a real existence; and the separation of the 'antero-lateral columns' into the 'anterior' and the 'lateral' columns (A A and L L) is only marked externally by the attachment of the nerve-roots. It is made more obvious internally, however, by the peculiar distribution of the *grey matter;* which, though by no means uniform throughout the Cord, usually presents (in a transverse section) the form of two somewhat crescent-shaped masses, whose convexities are turned towards each other, and are connected by the grey commissure, whilst their cornua are directed towards the surface of the cord; the posterior peak on each side nearly reaches the posterior lateral furrow, whilst the anterior, though the larger cornu, does not approach quite so near the surface. The grey matter is enveloped by the *white substance* of the columns, which are entirely composed of nerve-tubes, whose general direction is longitudinal. —The Spinal Cord of Man is by no means of uniform dimensions in every part of its length; and the proportions which the grey and white substances bear to one another in different parts, are extremely diverse (Fig. 81). Two principal enlargements are seen in the cervical and lumbar regions, at the origins of the large nerves forming the tracheal and crural plexuses; and these enlargements are chiefly due to an increase of the *grey* substance, which is comparatively deficient in the intervals. On the other hand, there is a regularly-progressive increase in the *white* substance, as we proceed from the lower to the

Fig. 82.

Transverse sections of *Human Spinal Cord* at different points, showing the proportional quantity and arrangement of grey and white matter at each:—1, opposite 11th dorsal vertebra; 2, opposite 1st dorsal; 3, opposite 8th dorsal; 4, opposite 4th dorsal; 5, opposite 7th cervical; 6, opposite 5th cervical; 7, opposite 3rd cervical; 8, section of medulla oblongata through centre of corpus olivare.

* The canal can only be distinguished in Man (being no more than 1-100th of an inch in diameter), by submitting thin transverse sections of the Cord to microscopic examination; whence it happens that its existence in the adult has been denied by Kolliker and many eminent anatomists. Its presence is much more obvious, however, in Fishes; in whose spinal cord the commissural connection between the two lateral halves is far less distinct than in higher Vertebrata.

higher portion of the cord,* and this fact of itself serves to indicate the probability, that the longitudinal columns serve (as formerly supposed) to establish a direct connection between the Encephalic centres and the roots of the Spinal nerves.

482. The *grey matter* or *vesicular substance* of the Spinal Cord, which is best seen in transverse section (Fig. 81), is by no means uniform in its texture throughout. Its anterior cornua, which are thicker and shorter than the posterior, are of a uniform grey colour, and they contain large well-developed nerve-cells (*d*), which usually present many radiating processes that seem to inosculate together, with delicate nerve-tubes of medium fineness passing in various directions between them. The central portion, which contains the canal, and which also forms the commissure, has a similar composition; but the cells are smaller, though still having long branching radiations, and the fibres are extremely fine, their tubularity being often indistinguishable. The anterior portion of the commissure, however, is purely fibrous, and is distinguished by some as the 'white commissure;' it does not, however, form an immediate connection between the two anterior columns, but brings each of them, as will be presently seen, into relation with the vesicular matter of the anterior cornu of the opposite side. The posterior cornua, longer and narrower than the anterior, contain a tract of vesicular matter (*e*) on each side, the cells of which resemble those of the central portion; this tract is invested by a more transparent layer, which has been distinguished as the *substantia gelatinosa*, but the composition of the latter only differs from that of the former in the smaller size of the nerve-cells, both having a large admixture of fine fibres. In no case has a direct continuity been distinguished between the nerve-fibres and the vesicles or their prolongations, though there are circumstances which seem to render such a connection probable.

483. The connection of the Nerve-roots of the Spinal Nerves with the several components of the Cord, and the course of the fibres after entering it, can only be made-out by means of *sections*; since all attempts to follow the course of individual fibres, or even that of fasciculi, by ordinary dissection, have as yet proved quite futile.† The following is an outline of the information which may thus be gained, from a comparison of transverse and longitudinal sections (Figs. 81 and 83).—The bundles that form the Posterior roots (Fig. 81, *c*, *c*, Fig. 83, P, P, P), consist of three kinds, which differ from each other partly in direction, and partly in the size of

* See Kölliker "Mikroskopische Anatomie," band ii. § 116, and "Manual of Human Histology" (Sydenham Society), vol. i. p. 420.—The statements in the text are in direct contradiction to the assertions of Volkmann (Art. 'Nervenphysiologie' in "Wagner's Handwörterbuch," band ii. pp. 482, et seq.), who affirms that the grey and white substances everywhere bear the same proportion one to the other, and that there is absolutely less white matter higher-up in the neck, than there is lower down in the cord. But his measurements were made upon the Spinal Cord of the Horse; and it seems not improbable, from the considerations to be hereafter stated (§ 487), that there may be an essential difference between Man and the lower Animals, as to the *proportion* which the root-fibres, terminating in the Spinal Cord itself, bear to those which pass between the roots of the nerves and the Encephalon.

† Mr. J. L. Clarke has succeeded, by the adoption of a peculiar method of preparation (for which see "Phil. Trans.," 1851, p. 607), in making sections of considerable dimensions, sufficiently transparent to allow the course of the fibres, and the contour of the nerve-cells and their prolongations, to be distinctly made-out.

their component filaments. The *first* kind, Fig. 83, *a, a, a*, (which seem to be limited to the upper part of the Cord) enter the posterior columns horizontally; and then, taking a longitudinal direction *down* the Cord, send fibres into the anterior grey substance (G), of which some bend upwards, and others downwards; part apparently becoming continuous with fibres of the anterior roots; whilst another part lose themselves among the fibres of the anterior columns, in which they may either proceed continuously to the head, or may pass along for a limited distance only, to emerge in the nerve-roots of some other segment. The *second* kind of bundles, *b, b, b*, also traverse the posterior columns horizontally and obliquely inwards; their further course may be best traced in a transverse section (Fig. 81). These fasciculi, which are composed of remarkably fine and delicate fibres, interlace so as to form with each other an intricate plexus; and from this, straight and distinct bundles enter the posterior cornua along their whole breadth, crossing the 'substantia gelatinosa' both obliquely and at right angles. Having thus entered the vesicular substance of the Cord, some of the fibres, after traversing it, emerge from it again, into either the posterior columns, or the posterior portion of the lateral columns; others pass towards the transverse commissure, through which they seem to make their way to the posterior and lateral columns of the opposite side; and others, again, form a fine network, which extends towards the anterior cornua. Of the fibres of a *third* set (Fig. 83, *c, c, c*), a part seem to become directly continuous with the fibres of the posterior columns; the larger proportion of them, however, cross these columns obliquely upwards, and enter the grey substance at different points; after passing into which, they can no longer be clearly followed, although

FIG. 83.

Longitudinal Section through Cervical enlargement of *Spinal Cord* of Cat:—A C, anterior white columns; A C′ portion showing the arrangement of the longitudinal fibres; P C, posterior white columns; G, grey substance between them (the vessels omitted, to avoid obscuring the course of the fibres); A, anterior roots of the nerves; P, posterior roots, consisting of three kinds; the first, *a*, crossing the posterior columns horizontally, and then passing obliquely downwards, across the grey substance, into the anterior columns; the second, *b*, traversing the posterior columns horizontally, and then distributing themselves through the grey substance; the third, *c*, for the most part becoming continuous with the longitudinal fibres of the posterior column.

some of them appear to form loops and then return to the white columns. —The fasciculi of fibres which constitute the anterior roots (Fig. [illegible] *b, b, b*, Fig. 83, A, A), on the other hand, traverse the anterior columns of the Cord nearly horizontally, and in straight and distinct bundles, which do not interlace with each other, until they reach the anterior cornu of the grey substance; on entering this, they break up into smaller bundles and separate fibres, which diverge in various directions, some pass-out again into the anterior, and others into the lateral columns of the same side; others, again, pass towards the anterior part of the commissure, in which they cross-over to the opposite side, entering its anterior and lateral columns; a considerable number plunge into the central substance of the grey cornu, and of these some become longitudinal, passing equally upwards and downwards, whilst others seem to traverse it horizontally, so as to come into relation (not improbably into actual continuity) with the posterior roots.

484. Thus we see that there are two very distinct courses pursued by the Root-fibres of the Spinal Nerves, in the substance of the Cord; the first *transverse*, the second *longitudinal*. The fibres belonging to the former category traverse the Cord horizontally or obliquely, and appear to pass-out in the other set of roots connected with the same segment, either on its own or on the opposite side of the median fissure. Of those belonging to the latter, a small part appears to connect the posterior roots directly with the posterior columns, without passing into the vesicular substance; but the remainder of those belonging to the posterior roots, first enter the grey matter of the Cord, and then emerge from it either into the posterior column, or into the posterior part of the lateral column, of their own or of the opposite half of the Cord; and, in like manner all the longitudinal fibres belonging to the anterior roots first enter the vesicular substance, and then pass-out from it into the anterior column, or the anterior part of the lateral column, of the same or of the opposite side. How far any of these longitudinal fibres proceed, however, either upwards or downwards in the Cord, must be acknowledged to be altogether undecided. It seems quite probable that *some* of them are (so to speak) properly longitudinal commissures, serving to connect the nerve-roots of one segment of the Cord, with the vesicular substance of another at a greater or less distance either above or below; and it has been recently maintained by several distinguished Neurologists, that *all* must probably be of this character, so that the Spinal Cord is the real centre of all the nerve-fibres connected with it. The principal argument for this doctrine (which seems to have originated with the anatomical researches of Stilling and Wallach,* and to have been first put-forth on a physiological basis by Messrs. Todd and Bowman†), arises from the asserted difficulty of supposing that its longitudinal columns *can* transmit any considerable number of nerve-fibres from the Encephalon to the Spinal nerve-roots. Thus it is urged by Dr. Todd, that it is highly improbable that the only channel by which the Will can influence the spinal nerves, should be (as generally admitted) that afforded by the Anterior Pyramids; since the whole bulk of these pyramids on *both* sides, taken together, scarcely equals that of *one* of the anterior portions of the antero-

* "Untersuchungen uber die Textur des Ruckenmarks," Leipzig, 1842.
† "Physiological Anatomy and Physiology of Man," Part ii., 1845.

lateral columns. Moreover, if there were a gradual giving-off of Encephalic fibres from the longitudinal columns into the roots of the nerves, the size of these columns ought progressively to diminish from above downwards; whereas it is asserted by Volkmann, who has strenuously upheld this doctrine (loc. cit.), that the size of the white columns presents no such diminution, but that it is everywhere proportional to the quantity of grey matter in the Cord. Thus in Serpents, the Spinal cord (as already noticed) is remarkable for its uniformity of dimension through its entire length, the absence of limbs preventing the necessity for an increase in the quantity of grey matter in any part, and the fibrous columns presenting a similar uniformity throughout; whereas, if the latter be really Encephalic, they should gradually dwindle-away from the head to the tail. Moreover it has been estimated by Volkmann, that the area of the whole Spinal Cord of a Boa, at its anterior part, is not more than *one-eleventh* part of the united area of the 221 pairs of nerves which are given-off from it. Further it is urged by Volkmann, that the white columns are absolutely-smaller in the cervical region, than they are in the lower part of the Cord; so that they would not suffice to convey even the lumbar columns upwards to the Encephalon, much less to transmit the fibres of all the intervening nerves in addition.

485. These and similar statements, however, have been recently met by Prof. Kolliker (loc cit.), whose researches have led him to a conclusion opposed to that of Volkmann, although he was at one time inclined to coincide with it. He has assured himself that *in Man*, the thickness of the white columns does augment from below upwards, and that the increase in the diameter of the Cord at the ganglionic enlargements is due to the augmentation of the grey matter only. Moreover, the diameter of the nerve-tubes in the Cord, especially at its upper part, is so much smaller than the diameter of the nerve-tubes of the Nerve-roots, that a large allowance must be made for this difference, in estimating the relative number of nerve-tubes in the fibrous columns of the Cord and in the Spinal Nerves; and he asserts from actual measurement, that it is by no means impossible for the fibrous strands of the former to contain all the nerve-tubes which issue from them in the latter. He has found himself unable, moreover, to detect *any* termination of the nerve-fibres in the vesicular substance of the spinal cord; and hence he thinks it probable that they all pass upwards to the brain.—On the other hand, the researches of Mr J. L. Clarke, which have been carried in some respects to a greater degree of minuteness than those of Prof. Kolliker, seem to confirm the belief that there *is* a set of fibres which never become longitudinal, and which, accordingly, have no other ganglionic centre than the vesicular substance of the segment of the Cord with which they come into immediate relation; whilst they also accord with those of Prof. Kolliker in rendering it extremely probable, that many of the longitudinal fibres of both roots, do pass continuously upwards to the Encephalon, most of them after traversing the grey nucleus, but some of those of the posterior roots without even entering the vesicular substance, so that *these* cannot have their ganglionic centre in the Cord at all. If the latter be among the fibres which pass-up through the Posterior Pyramids into the sensory tract of the Crura Cerebri (§ 490), their real ganglionic centres are the Thalami Optici.

486. That such is the real arrangement, is very strongly indicated by the analogous conformation of the ganglionated cord of Articulated animals; for it may be stated with tolerable certainty, that some of the root-fibres of their nerves pass along the purely-fibrous tract of that cord (which is far more readily separated from the vesicular, than it can be in Vertebrata), directly to the cephalic ganglia, which they thus bring into direct communication with all the nerve-trunks connected with the ganglionated cord; but that others, also becoming longitudinal, and running along those portions of the cord which intervene between and connect the ganglia of the different segments, pass into the nerve trunks that emerge from ganglia at a distance of one, two, three, or more segments above or below: whilst a large proportion of the root-fibres have their ganglionic centres in the ganglia which they respectively enter, and, after coming into relation with its vesicular substance, pass out again, either on the same or on the opposite side of the median plane.* Now the purely-fibrous tract of the ventral cord of the Articulata terminates in the Cephalic ganglia, which are homologous, as already remarked (§ 158), not with the whole Encephalon of Vertebrata, but with their 'sensory ganglia' alone; and thus analogy would lead us to suppose, that the fibrous strands of the Spinal Cord do *not* pass on continuously to the *Cerebrum*, but really extend no further upwards than the Corpora Striata, Thalami Optici, and the other ganglionic centres in connection with them, which lie along the floor of the cranial cavity. This view will be hereafter shown (Sect. 3) to be in harmony with anatomical and physiological facts, which indicate that the Cerebrum only receives its impulses to action through the medium of the Sensory Ganglia, and that it reacts upon the muscular apparatus only through the same channel. That some of the afferent fibres of the spinal nerves should ascend continuously upwards to the ganglia of tactile sense, in Man and other Vertebrata, as well as in Articulated animals, would seem a legitimate deduction from the fact, that such continuity obviously exists between the olfactory, visual, and auditory nerves, and *their* respective ganglionic centres, no intermediate apparatus of vesicular matter being interposed in their course; and, as we have seen (§ 483), the existence of such a continuity in regard to a part of the fibres of the posterior roots of the nerves is made extremely probable by the latest researches of Mr. J. L. Clarke.— A very remarkable confirmation, too, has been recently afforded to the doctrine of the constitution of the Spinal Cord here advocated, by the Pathological researches of Dr. Ludwig Turck,† who has shown that certain lesions of the Encephalon produce a degeneration of nerve-tissue in particular tracks, which may be traced continuously down the Spinal Cord, usually in the *anterior* column of the side affected, and in the *lateral* column of the opposite side; whilst, on the other hand, local lesions of

* See "Princ. of Comp. Phys.," § 648. The important facts here referred to have been chiefly substantiated by the researches of Mr. Newport; a very important addition to his statements, however, has been recently made by M. Gruther, who has demonstrated the actual continuity between the nerve-fibres and the caudate vesicles, in the ganglia of the ventral cord of the Leech.

† See his Memoir "Über secondäre Erkrankung einzelner Rückenmarksstränge und ihrer Fortsetzungen zum Gehirne," in "Denkschriften der Kaiserlichen Akademie der Wissenschaften," Wien, 1851; also "Zeitschrift der Gesell. der Aertze zu Wien," heft 10.

the Spinal Cord, as from caries of the vertebræ, or from the pressure of tumours, produce a like degeneration in certain tracks of the posterior columns, and sometimes also of the lateral columns, ascending towards the Encephalon. Thus it appears that the *posterior* fasciculi are liable to this secondary degeneration in the *centripetal* direction only, and the *anterior* in the *centrifugal* direction only, the degeneration taking place, in each case, in the direction in which they ordinarily transmit nerve-force. The mixed endowments of the *lateral* columns are also indicated by these phenomena.

487. We are not required, however, by the adoption of this view of the constitution of the Spinal Cord, to regard its Cephalic fibres as of *a different order* from those which pass from one of its own segments to another; for, considering the whole of the Cranio-Spinal axis as *one series of centres*, receiving the terminations of all the nerves, its longitudinal fibres are equally *commissural*, whether they establish the connection between the nerve-roots and vesicular matter of two adjacent segments, or whether they bring into the same structural relation the parts which are furthest removed in position. And thus we may regard all impressions upon the afferent nerves as first operating upon it (affecting the consciousness, or not, according as they reach the sensory ganglia, or are arrested in their progress thither), and all motor impulses, whether purely reflex, or originating in volitional direction or emotional excitement, as issuing immediately from it through the motor trunks. If such be the case, it does not seem at all improbable that there should be a difference in different tribes of animals, as to the proportion of fibres which have their centres in the Spinal cord and in the Sensorial centres respectively; for in those whose ordinary movements of progression, &c. are independent of sensation, being performed through the reflex action of the spinal cord, it might be expected that the chief connection of the spinal nerves should be with its own ganglionic substance, and that the bulk of the fibrous columns should be composed of commissural fibres resembling those which intervene between the separate portions of the ganglionic tract of the ventral cord of Articulata; whilst in like manner it might be anticipated that in Man, so large a part of whose movements are performed in obedience to a mental stimulus and under the guidance of sensation, the longitudinal strands should be chiefly composed of fibres that directly connect the sensorial centres with the roots of the spinal nerves. Such a difference would appear, from the comparative researches of MM. Volkmann and Kölliker, to exist between the structure of the spinal cord of the Horse and that of Man.

488. The *Medulla Oblongata*, or cranial prolongation of the Spinal cord, which bring it into connection with the Encephalic centres, is distinguished by the peculiar arrangement of its fibrous strands and of its nuclei of grey matter; and also by the peculiar distribution and endowments of the nerves connected with it (§ 510). The anatomical boundaries usually assigned to it, are the Pons Varolii above, and the Occipital foramen below; but these limits are purely artificial; and for physiological purposes, the course of its fibres must be traced much higher. The part thus marked-out has a bulb-like form, and presents, like the Cord of which it is the continuation, a posterior and an anterior median fissure. The former is deep and narrow, extending to the posterior border of a

layer of commissural fibres which forms the floor of the anterior fissure. The latter is wider and less deep; and its continuity with the anterior fissure of the spinal cord is interrupted by the decussation of the Anterior Pyramids, which is marked externally by the crossing of from three to five bundles of fibres from each side over to the other. This decussation may be considered as the physiological boundary between the Medulla Oblongata and the Spinal Cord. The surface of each lateral half is furrowed by grooves, which assist in marking-out the four principal strands of nerve-fibres that may be distinguished on either side; these are —I. The Anterior Pyramids or *Corpora Pyramidalia*; II. The Olivary Bodies, or *Corpora Olivaria*; III. The Restiform Bodies, or *Corpora Restiformia*; otherwise called *Processus a Cerebello ad Medullam Oblongatam*; IV. The Posterior Pyramids, or *Corpora Pyramidalia Posteriora*. The connections of these with the Brain above, and with the Spinal Cord below, will be presently traced.* The vesicular substance, on the other hand, is principally aggregated in three pairs of ganglionic centres; of which the *anterior* forms the nucleus of the Olivary body, the *lateral* of the Restiform, and the *posterior* of the Posterior Pyramidal.

489. The *Anterior Pyramids* (I) consist entirely of fibrous structure, and establish a communication between the 'motor tract' (Fig. 84, m t) of the Crura Cerebri, and the anterior and antero-lateral columns of the Spinal Cord. The principal part of their fibres decussate, and these as they pass from above downwards, dip-away from the anterior surface of the Cord, and connect themselves with its *middle* or *lateral* columns, instead of with its anterior, as was pointed-out by Rosenthal,† and more fully described by Dr. J. Reid.‡ A small part of the fibres of the pyramidal columns, however, do not decussate, but proceed downwards on the same side, into the corresponding *anterior* columns of the Spinal Cord.—II. The *Olivary* bodies are composed of fibrous strands, enclosing a grey nucleus (Fig. 84, *og*) on either side. The upward continuation of the former divides, while passing through the Pons Varolii, into two bands, one of which proceeds upwards and forwards as a part of the 'motor tract' (*m t*) of the Crus Cerebri, whilst the other (*o*) proceeds upwards and backwards to reach the Corpora Quadrigemina (c. q). The olivary columns are continuous inferiorly with the *anterior* columns of the Spinal Cord; and afford attachments to the anterior roots of the 1st and 2nd cervical nerves. The vesicular nucleus, which is known as the

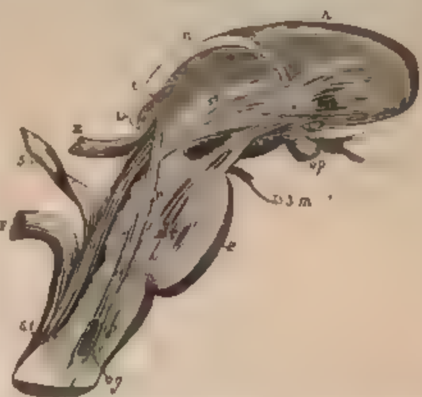
* Great diversities will be found in the accounts given of these connections by different authors, some of which are attributable to a variation in the use of terms, which has passed unnoticed. By the majority of Anatomists, the name of Corpora Restiformia is given to the *Cerebellar* Columns, and this designation, therefore, it seems advisable to retain. Some, however, and amongst them Dr. J. Reid, in his very excellent description of the Anatomy of the Medulla Oblongata ("Edinb. Med. and Surg. Journal," Jan. 1841), give that name to the columns that pass-up from the posterior division of the spinal cord to the crus cerebri (which are here called (after Sir C. Bell) the posterior pyramids) and apply the terms Posterior Pyramids to the Cerebellar column. The truth is that, as Sir C. Bell has justly observed, *all* the tracts of fibrous matter connecting the Brain with the Spinal Cord, have a somewhat *pyramidal* form; and it might be added that all have something of a *restiform* or cord-like aspect.

† "Ein Beitrag zur Encephalotomie," Weimar, 1815.

‡ "Edinb. Med. and Surg. Journ.," Jan. 1841; and "Physiol., Pathol., and Anat. Researches," CHAP. VII.

corpus dentatum, seems to be especially connected with the origins of the nerves concerned in the regulation of the movements of the tongue; thus we find that anteriorly a portion of the roots of the Hypoglossal, which is the motor nerve of the tongue, issue from it; whilst posteriorly a portion of the roots of the Glosso-pharyngeal, which is one of the sensory nerves of that organ, seem to terminate in it.—III. The *Restiform* bodies, in like manner, each consist of fibrous strands (F) enclosing a grey nucleus. The fibrous strands pass upwards into the Crura Cerebelli; whilst below they are chiefly continuous with the *posterior* columns of the Spinal Cord, having also some connection with the posterior part of the *middle* columns.

FIG. 84.



Dissection of the *Medulla Oblongata*, to show the connections of its several strands:—A, corpus striatum; B, thalamus opticus; C, D, corpora quadrigemina; E, commissure connecting them with the cerebellum; F, corpora restiformia; P, P, pons varolii; *st*, *st*, sensory tract; *mt*, *mt*, motor tract; *o*, olivary tract; *p*, pyramidal tract; *og*, olivary ganglion; *op*, optic nerve; 3 *m*, root of the third pair (motor); 5 *s*, sensory root of the fifth pair.

These Cerebellar columns also communicate, however, with the *anterior* columns of the Spinal Cord by a band of 'arciform' fibres, whose connections were first distinctly described by Mr. Solly;* of these there is a superficial set which unites itself with the pyramidal columns, and a deep set which comes into relation with the olivary. Their grey nucleus, or 'restiform ganglion,' appears to be the ganglionic centre of the Pneumogastric nerves, and of a portion of the roots of the Glossopharyngeal.—IV. The *Posterior Pyramids* are scarcely distinguishable externally from the Restiform bodies, of which they were formerly described as a constituent part; they form, however, the immediate boundaries of the posterior median fissure; and whilst superficially marked-off from the Restiform bodies by a slight groove, are more completely separated from them by their anatomical relations to the parts above and below. Their fibres establish a connection between the sensory tract (*st*, *st*) of the Crura Cerebri, and the posterior part of the *lateral* columns of the Spinal Cord, some of them passing also into its posterior columns. These fibrous tracts are stated by Mr. Solly† and Dr. Radclyffe Hall‡ to decussate, partially at least, whilst passing through the Pons Varolii.§ The grey nuclei of the Posterior Pyramids, situated immediately beneath the 'fourth ventricle' (which is nothing else than the

* "Philosophical Transactions," 1836.

† "The Human Brain," 2nd edit., p. 243.

‡ "Edinb. Med. and Surg. Journ.," July, 1847, Plate VII.

§ A decussation of the Posterior Pyramids was described by Sir C. Bell as occurring at the same level with the decussation of the Anterior Pyramids (Fig. 86, c); there can be no doubt, however, that this is an error, which probably originated in his having misinterpreted the appearance presented by the posterior aspect of the anterior decussation.

space left by the divergence of the Restiform and Posterior-Pyramidal tracts) are the ganglionic centres of the Auditory nerves, or the proper *Auditory ganglia;* and it is interesting to observe, that their seat precisely corresponds with that of the rudimental organ of hearing in many Invertebrata. (See PRINC. OF COMP. PHYS., § 711).

490. The Medulla Oblongata is usually considered as terminating at the

FIG. 85.

Course of the *Motor tract*, according to Sir C. Bell.—A, A, fibres of the Hemisphere converging to form the anterior portion of the crus cerebri; B, the same tract where passing the crus cerebri; C, the right Pyramidal body, a little above the point of decussation; D, the remaining part of the Pons Varolii, a portion having been dissected-off to expose B; 1, olfactory nerve, in outline; 2, union of optic nerves; 3, 3, motor oculi; 4, 4, patheticus; 5, 5, trigeminus; 6, 6, its muscular division; 7, 7, its sensory root; 8, origin of sensory root from the posterior part of the medulla oblongata; 9, abducens oculi; 10, auditory nerve; 11, facial nerve; 12, eighth pair; 13, hypoglossus; 14, spinal nerves; 15, spinal accessory of right side, separated from par vagum and glosso-pharyngeal.

lower border of the Pons Varolii; but it will be convenient here to trace upwards the strands by which it is connected with the higher Encephalic centres, as a clearer idea of its anatomical and physiological relations will thus be obtained.—The Pons is chiefly composed of transverse fibres, which constitute the great commissure of the Cerebellum; and these fibres not only *surround* the longitudinal bands which connect the Cerebral mass with the Spinal Cord, but *pass through* them; so as in some degree to isolate the two lateral halves from one another, and to form a complete septum between the anterior and posterior portions of each. These *anterior* and *posterior* tracts of the Crura Cerebri are respectively subservient to the *motor* and the *sensory* functions; as is clearly indicated by the endowments of the nerves which are connected with each respectively.*—The *Motor* tract (Fig. 85) is brought into view, by simply raising the superficial layer of the Pons, and following upwards and downwards the longitudinal fibres which then present themselves. These fibres may be traced *upwards* into the Corpora Striata, and *downwards* into the Anterior Pyramids and a portion of the Olivary columns; so that they connect the Corpora Striata with the *anterior*, and with the anterior portion of the *lateral*, columns of the Spinal Cord. With this

Fig. 86.

Course of the *Sensory tract* according to Sir C. Bell.—A, Pons Varolii; B, B, sensory tract separated; C, union of posterior columns; D, D, posterior roots of spinal nerves; E, sensory roots of fifth pair.

tract we find connected—passing from below upwards—the roots of the Spinal Accessory, the Hypoglossal, the Facial or Portio Dura of the 7th, the 6th or Abducens oculi, the smaller root of the 5th (which can be

* This was first clearly shown by Sir C. Bell in the "Philos. Transact.," 1835.

traced to the part of the Olivary column that passes upwards to the Corpora Quadrigemina), the 4th or Trochlearis (which is attached to the same part of the tract), and the 3rd or Oculo motor nerve; all of which are purely motor in their endowments.—The *Sensory* tract (Fig. [illegible]) is displayed, by opening the Medulla Oblongata on its posterior aspect, and then separating and turning aside the Restiform columns, so as to bring into view the posterior pyramids. Its fibres may be traced *upwards* into the Thalami Optici; whilst they pass, through the Posterior Pyramids, into the posterior portion of the *lateral* columns, and also into the *posterior* columns of the Spinal Cord. With this tract are connected nearly the whole of the roots of the Pneumogastric and Glosso-pharyngeal nerves, and the larger or sensory root of the 5th pair.—The greater part of the Motor tract decussates, where the Anterior Pyramids become continuous with the lateral columns of the Spinal Cord; on the other hand the greater part of the Sensory tract decussates in its passage through the Pons Varolii.—The following tabular view may assist in conveying a knowledge of this somewhat intricate piece of Anatomy; which, when once mastered, will be found to be really simpler than it appears.

Spinal Cord.	Medulla Oblongata	Brain
	Anterior or Motor Division.	
Anterior Columns	Arciform fibres of Olivary and Anterior Pyramidal columns	*Cerebellum*
	Posterior portion of Olivary columns	*Corpora Quadrigemina*
	Anterior portion of Olivary columns	*Corpora Striata*
	Non decussating portion of Anterior Pyramidal columns	
Anterior portion of *Lateral Columns.*	Decussating portion of Anterior Pyramidal columns	
	Posterior or Sensory Division.	
Posterior portion of *Lateral Columns.*	Decussating portion (?) of Posterior Pyramidal columns	*Thalami Optici.*
Posterior Columns	Non-decussating portion (?) of Posterior Pyramidal columns	
	Restiform columns	*Cerebellum*

491. *Nerves of the Spinal Axis.*—With the Spinal Cord (in its limited sense) there are connected thirty-one pairs of nerves; each of which corresponds to a vertebral segment of the body, and has two sets of roots, an anterior and a posterior, differing in their functional endowments, as already described (§ 472). The anterior roots are usually the smaller; and this is particularly the case with those of the cervical nerves, in which the posterior roots are of remarkable comparative size. In the first Cervical or 'sub-occipital' pair, the anterior roots are sometimes wanting; but there is then a derivation of fibres from the Spinal Accessory, or from the Hypoglossal, or from both. The two roots of the ordinary Spinal nerves unite immediately beyond the ganglion, which is situated on the posterior one; and the trunk thus formed separates immediately into two divisions,—the anterior and posterior,—each of which contains both afferent and motor fibres. These divisions, of which the anterior is by far the larger, proceed to the anterior and posterior parts of the body respectively; and are chiefly distributed to the skin and the muscles. The anterior branch is that which communicates with the Sympathetic nerve.—In addition to these, however, the cranial prolongation of the Spinal Axis is the centre of all the cephalic

nerves, save those of special sensation, which terminate in their respective ganglia; and as these cephalic nerves are for the most part distinguished by the peculiarity of their endowments, they require to be separately noticed.

492. The pair of nerves commonly designated as the *Fifth* of the Cephalic series, or as the *Trigeminus*, is the one which more nearly resembles the ordinary Spinal nerves, than does any other of those originating within the cranium. It possesses two distinct sets of roots, of which one is much larger than the other; on the larger root, as on the posterior and larger root of the Spinal nerves, is a distinct ganglion, known as the 'Gasserian'; and the fibres arising from the smaller root do not blend with those of the larger, until the latter have passed through this ganglion. The trunk of the nerve separates into three divisions,—the Ophthalmic, the Superior Maxillary, and the Inferior Maxillary; and it can be easily shown, by careful dissection, that the fibres of the smaller root pass into the last of these divisions alone. When the distribution of this nerve is carefully examined, it is found that the *first* and *second* divisions of it proceed almost entirely to the Skin and Mucous surfaces, only a very small proportion of their fibres being lost in the muscles; whilst of the branches of the *third* division, a large number are distinctly Muscular. Hence analogy, and the facts supplied by anatomical research, would lead to the conclusion, that the first two divisions are nerves of sensation only, and that the third division combines sensory and motor endowments. Such an inference is fully borne-out by experiment. When the whole trunk is divided within the cranium by the penetration of a sharp instrument (which Magendie, by frequent practice, has been able to accomplish), evident signs of acute pain are given. After the incision has been made through the skin, the animal remains quiet until the nerve is touched; and when it is pressed or divided, doleful cries are uttered, which continue for some time, showing the painful effect of the irritated state of the cut extremity. The common sensibility of all the parts supplied by this nerve is entirely destroyed on the affected side. The jaw does not hang loosely, because it is partly kept-up by the muscles of the other side; but it falls in a slight degree, and its movements are seen, when carefully observed, to be somewhat oblique. If the trunk be divided on each side, the whole head is deprived of sensibility, and the animal carries it in a curious vacillating manner, as if it were a foreign body.—If the anterior or *Ophthalmic* branch only be divided, all the parts supplied by it are found to have lost their sensibility, but their motions are unimpaired; and all experiments and pathological observations concur in attributing to it sensory endowments only. The only apparent exception is in the case of the naso-ciliary branch, since there is good reason to believe that the long root of the ciliary ganglion and the long ciliary nerves possess motor powers; but these appear to be derived from the Sympathetic or from the 3rd pair. When the whole nerve, or its anterior branch, is divided in the rabbit, the pupil is exceedingly contracted, and remains immovable; but in dogs and pigeons it is dilated. The pupil of the other eye is scarcely affected; or, if its dimensions be changed, it soon returns to its natural state. The eyeball, however, speedily becomes inflamed; and the inflammation

usually runs-on to suppuration and complete disorganization. The commencement of these changes may be commonly noticed within twenty-four hours after the operation, and they appear to be due to the want of the protective secretion, which is necessary to keep the mucous surface of the eye in its healthy condition, and which is not formed when the sensibility of that surface is destroyed.—The *Superior Maxillary* branch, considered in itself, is equally destitute of motor endowments with the ophthalmic; but its connection with other nerves, through the spheno-palatine ganglion and its anastomosing twigs, may introduce a few motor fibres into it.—The *Inferior Maxillary* branch is the only one which possesses motor as well as sensory endowments from its origin; but its different subdivisions possess these endowments in varying proportions, some being almost exclusively motor, and others as completely of a sensory character. The latter is probably the nature of the Lingual branch, and there seems good reason to believe, as will hereafter be shown (§ 495), that this ministers not only to the tactile sensibility of the tongue, but to the sense of Taste. The muscles put in action by this division, are solely those concerned in the masticatory movements.—The 5th pair is connected, in different parts of its course, with a number of small ganglia belonging to the Sympathetic system. One of the most interesting of these ganglia is the *Ophthalmic* or *Ciliary* (Fig. 87, 29), which is the centre whence the eyeball derives its supply of nerves, sensory, motor, and sympathetic. This ganglion derives its sensory fibres by its 'long root' from the nasal branch of the Ophthalmic division of the 5th pair; its motor fibres, by the 'short root' from the 3rd pair; whilst by another small root, it is connected with the cavernous plexus of the Sympathetic system,—thus presenting a sort of miniature representation of the entire series of Sympathetic ganglia, and of their connections with the Cerebro-spinal system.*

* The functions of this ganglion have been made the subject of particular investigation by Dr. C. Radclyffe Hall ("Edinb. Med. and Surg. Journal," 1846-48), whose most important results are as follows:—

1. The size of the ciliary ganglion is always in direct proportion to the activity of the iris, which in turn always bears a direct relation to the strength and acuteness of vision, and to the nocturnal habits of the animal, and implies a proportionate development of the internal vascular apparatus of the eye.

2. The ganglion is always more intimately connected with the 3rd pair, than with any other, the size of the short root being always in direct relation to that of the ganglion, and the ganglion being sometimes a mere swelling on the trunk of the nerve.

3. The fibres derived from the 5th pair do not terminate in the ganglion, but pass onwards through it to the ciliary plexus.

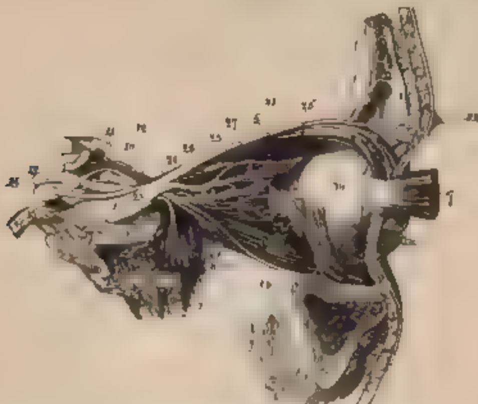
4. In the Rabbit, the iris receives fibres from the 6th pair which do not pass through the ganglion; and it is through this that the contraction of the pupil is produced in that animal by irritation of the 5th pair, which will not produce any effect upon the pupil of the Dog, Cat, or Pigeon, so long as it does not affect the brain to the extent of producing vertigo, nor affect the visual sense in any other way.

5. Irritation of the 5th nerve does not in any animal affect the action of the iris, after the division of the cerebral connections of all the other ocular nerves, so that its influence over the movements of the iris must be reflected through the encephalic centres, not through the ophthalmic ganglion.

6. The function of the ganglionic centre itself, as a part of the Sympathetic system, seems to be to bring the 'organic actions' of the eyeball, especially its supply of [illegible], into harmony with its functional activity, this harmony being produced by the passage of the cerebro-spinal nerves through the ganglion, which excites the synergetic action of its own vesicles and nerve fibres.

493. The *Third*, *Fourth*, and *Sixth* pairs, together make-up the apparatus of motor nerves, by which the muscles of the Orbit are called into action. The 3rd pair supplies the greater number of the muscles; the 4th being confined to the Superior Oblique, and the 6th to the External Rectus. Of these nerves, the 3rd pair is the only one which

FIG. 87



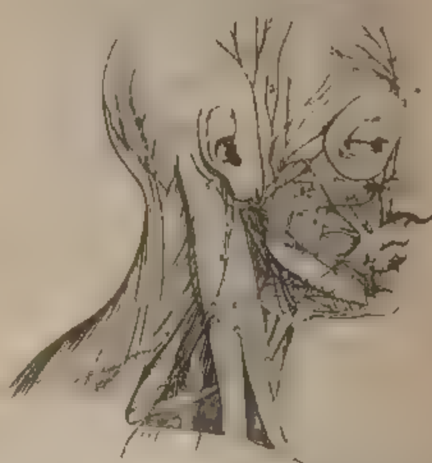
The *Nerves of the Orbit* seen from the outer side.—1. Section of the frontal bone; immediately behind the numeral is the frontal sinus, and, in front, the integument. 2. The superior maxillary bone; the section in front of the numeral exhibits the maxillary sinus. 3. Part of the sphenoid bone. 4. The levator palpebræ and superior rectus muscles. 5. The superior oblique muscle. 6. The inferior oblique muscle. 7. The ocular half of the external rectus muscle drawn forwards. 8. The orbital half of the external rectus muscle turned downwards. On this muscle the sixth nerve is seen dividing into branches. 9. The inferior rectus muscle. 10. The optic nerve. 11. The internal carotid artery emerging from the cavernous sinus. 12. The ophthalmic artery. 13. The third nerve. 14. The branch of the third nerve to the inferior oblique muscle. Between this and the sixth nerve (8) is seen the branch which supplies the inferior rectus; its branch to the ophthalmic ganglion is seen proceeding from the upper side of the trunk of the nerve, at the bottom of the orbit. 15. The fourth nerve. 16. The trunk of the fifth nerve. 17. The Gasserian ganglion. 18. The ophthalmic nerve. 19. The superior maxillary nerve. 20. The inferior maxillary nerve. 21. The frontal nerve. 22. Its division into branches to supply the integument of the forehead. 23. The lachrymal nerve. 24. The nasal nerve; the small nerve seen in the bifurcation of the nasal and frontal nerve, is one of the branches of the upper division of the third nerve. 25. The nasal nerve passing over the internal rectus muscle to the anterior ethmoidal foramen. 26. The infra-trochlear nerve. 27. A long ciliary branch of the nasal; another long ciliary branch is seen proceeding from the lower aspect of the nerve. 28. The long root of the ophthalmic ganglion, proceeding from the nasal nerve, and receiving the sympathetic root which joins it at an acute angle. 29. The ophthalmic ganglion, giving off from its fore-part the short ciliary nerves. 30. The globe of the eye.

exhibits any appearance of sensibility, when its trunk is irritated; but this sensibility is not nearly so great as that of the 5th pair; and as there is no reason to believe that it is really possessed by the 3rd in virtue of its direct connection with the nervous centres, it is probably imparted by the anastomosis of that nerve with the 5th,—some filaments of which may pass backwards as well as forwards, so as to confer sensibility on the trunk of the 3rd, above as well as beyond their point of entrance.—The peculiar mode in which those motor nerves ordinarily excite the muscles to action, under the guidance of the visual sense, will be considered in the next Section (§§ 542, 546). Although commonly ranked as cephalic nerves, they have no direct connection with the Cerebrum; their real origin being from the upper part of the Spinal

Axis (§ 490). The roots of the 3rd pair may be traced into direct connection with the Corpora Quadrigemina; a fact of considerable physiological importance, as will hereafter appear.—The chief actions of a purely-*reflex* nature to which this group of nerves ordinarily ministers, are the government of the diameter of the pupil, which is accomplished through the Third pair, and the rolling of the eyeball beneath the upper lid during sleep, as well as in the efforts of sneezing, coughing, &c. But irregular movements of the eyeballs, which must be referred to the same group, are continually seen to accompany various abnormal forms of convulsive action.

494. The *Portio Dura* of the *Seventh* pair, or *Facial* nerve, has been usually considered, subsequently to the researches of Sir C. Bell, as a nerve

FIG. 88



The distribution of the *Facial Nerve*, and the branches of the Cervical plexus.—1. The facial nerve, escaping from the stylo-mastoid foramen, and crossing the ramus of the lower jaw; the parotid gland has been removed in order to show the nerve more distinctly. 2. The posterior auricular branch; the digastric and stylo-mastoid filaments are seen near the origin of this branch. 3. Temporal branches, communicating with (4) the branches of the frontal nerve. 5. Facial branches, communicating with (6) the infra-orbital nerve. 7. Facial branches, communicating with (8) the mental nerve. 9. Cervico-facial branches, communicating with (10) the superficialis colli nerve, and forming a plexus (11) over the submaxillary gland. The distribution of the branches of the facial in a radiated direction over the side of the face constitutes the pes anserinus. 12. The auricularis magnus nerve, one of the ascending branches of the cervical plexus. 13. The occipitalis minor, ascending along the posterior border of the sterno-mastoid muscle. 14. The superficial and deep descending branches of the cervical plexus. 15. The spinal accessory nerve, giving-off a branch to the external surface of the trapezius muscle. 16. The occipitalis major nerve, the posterior branch of the second cervical nerve.

of motion only; but some physiologists have maintained, that it both possesses sensory endowments, and arises by a double root. According to Valentin, however, who has experimented on the roots exposed within the cranium, it possesses no sensory endowments at its origin; since, when these roots were touched, the animals gave no signs of pain, though violent muscular movements were excited in the face. Subsequently to

its first entrance into the canal by which it emerges, however, it anastomoses with other nerves; and thus *sensory* fibres are introduced into it from many different sources (anteriorly from the 5th pair, and posteriorly from the cervical nerves), which cause irritation of several of its branches to produce pain. The number and situation of the anastomoses vary much in different animals; so that it is impossible to make any very comprehensive statement in regard to them.—Experimental researches leave no doubt that the Portio Dura is the *general motor* nerve of the face; ministering to the influence of Volition and of Emotion, and also being the channel of the reflex movements concerned in respiration, as of other automatic actions of the muscles; but not being in the least concerned in the act of mastication.

495. Although the functions of the *Glosso-Pharyngeal* nerve have been heretofore alluded-to in part, several questions still remain to be discussed in regard to them. Reasons have been given for the belief, that it is chiefly an afferent nerve,—scarcely having any *direct* power of exciting muscular contraction, but conveying impressions to the Medulla Oblongata, which produce *reflex* movements of the motor nerves concerned in deglutition (§ 81). This view of its function was deduced by Dr. J. Reid from minute anatomical investigation, and from a large number of experiments. Some experimenters assert, that they have succeeded in exciting *direct* muscular actions through its trunk; but these actions seem to be limited to the stylo-pharyngei and palato-glossi muscles.—Much controversy has taken place on the question, whether this nerve is to be regarded as ministering, partly or exclusively, to the sense of Taste; and many high authorities have ranged themselves on each side. The question involves that of the function of the Lingual branch of the 5th pair; and it is partly to be decided by the anatomical relations of the two nerves respectively. The Glosso-pharyngeal is principally distributed on the mucous surface of the fauces, and on the back of the tongue; but according to Valentin, it sends a branch forwards, on either side, somewhat beneath the lateral margin, which supplies the edges and inferior surface of the tip of the tongue, and inosculates with the Lingual branch of the 5th. On the other hand, the upper surface of the front of the tongue is supplied by this Lingual branch. The experiments of Dr. Alcock, whose conclusions are borne out by Dr. J. Reid, decidedly support the conclusion, that the gustative sensibility of *this* part of the tongue is chiefly due to the latter nerve, being evidently impaired by division of it. On the other hand, it is equally certain, that the sense of taste is not destroyed by section of the Lingual nerve on each side; and it seems also well ascertained, that it is impaired by section of the Glosso-pharyngeal nerve.—The pathological evidence bearing upon this point appears somewhat contradictory. Numerous cases have been recorded,* in which both common and gustative sensation were destroyed in the parts of the tongue supplied by the 5th pair, when that nerve was paralysed; in some of these, the loss of the sense of taste appeared to extend itself to the base of the tongue, but then there was evidence that the Glosso-pharyngeal was involved in

* See especially the cases recorded by Romberg, in "Muller's Archiv.," 1838, heft iii.; Todd and Bowman, in "Physiological Anatomy," vol. i. p. 445; and Dixon, in "Med. Chir. Trans.," vol. xxviii.

the paralysis. On the other hand, cases of paralysis of the 5th pair are related by Mr. Noble and by Vogt,* in which common sensation was lost, whilst the sense of taste remained in the same parts; and Mr Noble relates another case,† in which there was loss of taste without impairment of common sensation. The cases of Mr. Noble and Vogt would seem to indicate that the 5th pair does not minister to the sense of Taste. But, as Dr. J. Reid has justly observed, we have no evidence that *all* the filaments of the fifth Pair sent to the tongue were affected; and there is believed to be no case on record, in which the whole of the 5th pair, or of its 3rd branch, was found to be diseased after death, and in which during life the sense of Taste had been retained in the anterior and middle parts of the tongue. Hence these cases only serve to indicate what is probable on other grounds, viz., that the filaments which convey gustative impressions are not the same with those that minister to common sensation.—On the whole, then, it seems to be proved by anatomical and experimental evidence, that both the Glosso-pharyngeal and the Fifth pair minister alike to the *tactile* and to the *gustative* sense, and there is nothing in the pathological facts just noticed, that militates against this conclusion. There seems good reason to believe the Glosso-pharyngeal to be exclusively the nerve, through which the impressions made by disagreeable substances taken into the mouth are propagated to the Medulla Oblongata, so as to produce *nausea* and to excite efforts to vomit.

Fig. 98.

Origin and distribution of the *Eighth Pair* of nerves. 1, 3, 4. The Medulla Oblongata. 1. The Corpus Pyramidale of one side. 3. The Corpus Olivare. 4. The Corpus Restiforme. 2. The Pons Varolii. 5. The Facial nerve. 6. The origin of the *Glosso-pharyngeal* nerve. 7. The ganglion of Andersch. 8. The trunk of the nerve. 9. The *Spinal Accessory* nerve. 10. The ganglion of the *Pneumogastric* nerve. 11. Its plexiform ganglion. 12. Its trunk. 13. Its pharyngeal branch forming the pharyngeal plexus (14) assisted by a branch from the glosso-pharyngeal (8) and one from the superior laryngeal nerve (15). 16. Cardiac branches. 17. Recurrent laryngeal branch. 18. Anterior pulmonary branches. 19. Posterior pulmonary branches. 20. Œsophageal plexus. 21. Gastric branches. 22. Origin of the Spinal Accessory nerve. 23. Its branches distributed to the sterno-mastoid muscle. 24. Its branches to the trapezius muscle.

496. The functions of the *Pneumogastric* nerve at its *roots* have been made the subject of particular examination by various experimenters, some of whom (for instance, Valen-

* "Medical Gazette," Oct. 25, 1834; and "Muller's Archiv.," 1840, p. 72.

† "Medical Gazette," Nov. 21, 1835.

tin, Longet, and Morganti) have concluded that it *there* possesses no motor power, but is entirely a sensory or rather an afferent nerve. According to these, if the roots be carefully separated from those of the Glosso-Pharyngeal, and (which is a matter of some difficulty) from those of the Spinal Accessory nerve, and be then irritated, no movements of the organs supplied by its trunk can be observed: whilst, if the roots be irritated when in connection with the nervous centres, muscular contractions, evidently of a reflex character, result from the irritation; and strong evidences of their sensibility are also given. It has been further asserted that, when the roots of the Spinal Accessory nerve are irritated, no indications of sensation are given; but that the muscular parts supplied by the Pneumogastric, as well as by its own trunk, are made to contract, even when the roots are separated from the nervous centres; so that these roots must be regarded as the channel of the motor influence, transmitted to them from the Medulla Oblongata. Where the Pneumogastric swells into the jugular ganglion, an interchange of fibres takes place between it and the Spinal Accessory; and it seems clear that the pharyngeal branches, which are among the most decidedly motor of all those given-off from the Pneumogastric, may in great part be traced backwards into the Spinal Accessory. —But, on the other hand, an equally numerous and trustworthy set of experimenters (among whom may be mentioned J. Reid, Muller, Volkmann, Stilling, Wagner, and Bernard) are opposed to this opinion; maintaining that the Pneumogastric has motor roots of its own; and affirming that irritation of the roots of the Spinal Accessory produces little or no effect on the muscles supplied by the trunk of the Par Vagum. —The fact appears to be, that the roots of these two nerves are so commingled, that it is difficult to say what belong exclusively to each. Some of the fibres usually considered to belong to the Spinal Accessory, are occasionally seen to connect themselves with the roots of the Pneumogastric, even before the ganglion is found upon it. And it seems most probable, that while the roots of the Spinal Accessory are entirely motor, those of the Pneumogastric are *chiefly* afferent; that they inosculate with each other, in a degree which may vary in different species, and even in different individuals; and that the Pneumogastric may thus derive additional motor fibres from the Spinal Accessory, whilst it supplies that nerve with afferent fibres. Further, it appears probable, from the researches of M. Cl. Bernard, to be presently noticed (§ 498), that the motor fibres properly belonging to the Pneumogastric are adequate to the regulation of those movements of the larynx and other portions of the air-passages, which are concerned in the *passive* act of Respiration.

497. There can be no doubt that the *trunk* of the Pneumogastric is to be considered as a nerve of double endowments; although it is certain that these endowments are very differently distributed amongst its branches. That the nerve is capable of conveying those impressions, which become *sensations* when communicated to the sensorium, is experimentally proved by the fact, that, when its trunk is pinched, the animal gives signs of acute pain: but it is also evident from the painful consciousness we occasionally have, of an abnormal condition of the organs which it supplies. Thus, the suspension of the respiratory movements

gives rise to a feeling of the greatest uneasiness, which must be excited by impressions conveyed through this nerve from the lungs: and an inflamed state of the walls of the air passages causes the contact of cool and dry air to produce distressing pain and irritation: yet of the ordinary impressions conveyed from these organs, which are concerned in producing the respiratory movements, and in regulating the actions of the glottis, we are not conscious. The same may be said of the portion of the nerve distributed upon the alimentary tube: for the pharyngeal branches are almost exclusively motor, the afferent function being performed by the Glosso-pharyngeal; whilst the œsophageal and gastric are both afferent and motor, conveying impressions which excite reflex movements in the muscles of those parts, but which do not become sensations except under extraordinary circumstances. The participation of this nerve in the operations of Deglutition, Digestion, Circulation, and Respiration, and the effects of injury to its trunk or branches, have already been considered in the account of those functions.

498. In regard to the functions of the *Spinal Accessory* nerve, also, there has been great difference of opinion; the peculiarity of its origin and course having led to the belief, that some very especial purpose is answered by it. The roots of this nerve arise from the side of the Spinal Cord, as low down as the 5th or 6th cervical nerve, and the trunk formed by them ascends into the cranium between the anterior and posterior roots of the spinal nerves. From the recent researches of Mr. J. L. Clarke,* it appears that these roots may be traced into a special tract of vesicular matter, which descends as far as the lumbar enlargement. The predominance of motor fibres in its roots, its inosculation with the Pneumogastric, and its probable reception of sensory fibres from the latter, whilst imparting to it motor filaments, have been already referred-to (§ 496). As its trunk passes through the foramen lacerum, it divides into two branches, of which the internal, after giving off some filaments that assist in forming the pharyngeal branch of the Pneumogastric, becomes incorporated with the trunk of that nerve, whilst the external proceeds outwards, and is finally distributed to the sterno-cleido-mastoideus and trapezius muscles, some of its filaments inosculating with those of the cervical plexus. When the external branch is irritated before it perforates the sterno-mastoid muscle, vigorous convulsive movements of that muscle and of the trapezius are produced; and the animal does not give any signs of pain, unless the nerve be firmly compressed between the forceps, or be included in a tight ligature. Hence it may be inferred, that the functions of this nerve are chiefly motor, and that its sensory filaments are few in number. Further, when the nerve has been cut-across, or firmly tied, irritation of the lower end is attended by the same convulsive movements of the muscles, whilst irritation of the upper end in connection with the spinal cord, is unattended with any muscular movement. Hence it is clear that the motions occasioned by irritating it are of a direct, not of a reflex character. The same muscular movements are observed on irritating the nerve in the recently-killed animal, as during life. According to Sir C. Bell, the Spinal Accessory is a purely Respiratory nerve, whose office it is to excite the involuntary or automatic movements of the muscles it supplies, which share in the act

* "Philosophical Transactions," 1851, p. 613.

of respiration; and he states that the division of it paralyses, as muscles of respiration, the muscles to which it is distributed; though they still perform the voluntary movements, through the medium of the spinal nerves. Both Valentin and Dr. J. Reid, however, positively deny that this is the case; and Dr. Reid's method of experimenting was well adapted to test the truth of the assertion.* The functions of this nerve have been made the subject of special examination by M. Cl. Bernard;† who has arrived at the conclusion that the Spinal Accessory is a purely motor nerve, whose action is not essential to the *ordinary* movements of respiration, these being provided-for by the Pneumogastric and ordinary Spinal nerves, but that its special function is to bring the respiratory movements into accordance with the requirements of Animal life, adapting the actions of the muscles of the larynx and thorax to the production of *voice*, or to general muscular *effort*. The internal branch, which is specially distributed, with the fibres of the Pneumogastric, to the pharynx and larynx, is peculiarly subservient to the former of these purposes; and the external to the latter. This conclusion is sufficiently in accordance with the results obtained by other experimenters, to be received as a probable explanation of the facts which have been observed by them.

499. The *Hypoglossal* nerve, or *Motor Linguæ*, is the only one which, in the regular order, now remains to be considered. That the distribution of this nerve is restricted to the muscles of the tongue, is a point very easily established by anatomical research; and accordingly we find that, long before the time of Sir C. Bell, Willis had spoken of it as the nerve of the motions of articulation, whilst to the Lingual branch of the 5th pair he attributed the power of exercising the sense of taste; and he distinctly stated, that the reason of this organ being supplied with two nerves, is its double function. The inference that it is chiefly, if not entirely, a *motor* nerve, which has been founded upon its anatomical distribution, is supported also by the nature of its origin, which is usually from a single root, corresponding to the anterior root of the Spinal nerves. Experiment shows that, when the trunk of the nerve is stretched, pinched, or galvanized, violent motions of the whole tongue, even to its tip, are occasioned; and also, that similar movements take place after division of the nerve, when the cut end most distant from the brain is irritated. In regard to the degree in which this nerve possesses sensory properties, there is some difference of opinion amongst physiologists, founded, as it would seem, on a variation in this respect between different animals. Indications of pain are usually given, when the trunk is irritated after its exit from the cranium; but these may proceed from its free anastomosis with the cervical nerves, which not improbably impart sensory fibres to it. But in some Mammalia, the hypoglossal nerve has been found to possess a small posterior root with a ganglion; this is the case in the Ox, and also in the Rabbit; and in the latter animal, Valentin states that

* See his "Physiol., Pathol., and Anat. Researches," p. 151; and "Edinb. Med. and Surg. Journ.," Jan., 1838.

† 'Recherches Expérimentales sur les Fonctions du Nerf Spinal,' in "Archives de Médecine," 1844.—This Memoir, having gained the prize given by the Académie des Sciences for experimental physiology in 1845, has been printed in the "Recueil des Savants étrangers," tom. xi., 1851; and the author states that since the first publication of his researches, he has confirmed his original conclusions by the repetition and variation of his experiments.

the two trunks pass-out from the cranium through separate orifices, and that, after their exit, one may be shown to be sensory, and the other to be motor. Hence, this nerve, which is the lowest of those that originate in the cephalic prolongation of the spinal cord generally known as the medulla oblongata, approaches very closely in some animals to the regular type of the spinal nerves; and though in Man it still manifests an irregularity, in having only a single root, yet this irregularity is often shared by the first cervical nerve, which also has sometimes an anterior root only.—The Hypoglossal nerve is distributed not merely to the tongue, but to the muscles of the neck which are concerned in the movements of the larynx; and the purpose of this distribution is probably to associate them in those actions, which are necessary for articulate speech. Though *all* the motions of the tongue are performed through the medium of this nerve, yet it would appear, from pathological phenomena, to have at least two distinct connections with the nervous centres; for in many cases of paralysis, the masticatory movements of the tongue are but little affected, when the power of articulation is much injured or totally destroyed; and the converse may be occasionally noticed. When this nerve is paralysed on one side, in hemiplegia, it will be generally observed that the tongue, when the patient is directed to put it out, is projected *towards* the palsied side of the face: this is due to the want of action of the lingual muscles of that side, which do not aid in pushing-forward the tip; the point is consequently directed only by the muscles of the other side, which will not act in a straight direction, when unantagonized by their fellows. It is a curious fact, however, that the Hypoglossal nerve seems not to be always palsied on the same side with the Facial, but sometimes on the other. This has been suggested to be due to the origination of the roots of this nerve from near the point at which the pyramids of the medulla oblongata decussate, so that some of its fibres come-off, like those of the spinal nerves, without crossing, whilst others are transmitted to the opposite side, like those of the higher cephalic nerves; and the cause of paralysis may affect one or other of these sets more particularly. Whatever may be the validity of this explanation, the circumstance is an interesting one and well worthy of attention.*

500. The *general homology* of the Cephalic nerves, considered with reference to the ordinary Spinal, constitutes a study of much interest. It appears, from what has been already stated, that the Pneumogastric, Spinal Accessory, Glosso-pharyngeal, and Hypoglossal nerves, may be considered nearly in the light of ordinary Spinal nerves. They all take their origin exclusively in the Medulla Oblongata; and the want of correspondence in position, between their roots and those of the Spinal nerves, is readily accounted-for, by the alteration in the direction of the columns of the Spinal cord, which not only decussate laterally, but, as it were, antero-posteriorly (§ 489). The Hypoglossal, as just stated, not unfrequently possesses a sensory in addition to its motor root. The

* It may be questioned, however, whether the Hypoglossal is really paralyzed on the opposite side from the Facial in such cases. An instance has been communicated to the Author by Dr W. Budd, in which the hypoglossal nerve was completely divided on one side, and yet the tip of the tongue, when the patient was desired to put it out, was sometimes directed *from* and sometimes *towards* the palsied side; showing that the muscles of either half are sufficient to give any required direction to the whole.

Glosso-pharyngeal, which is principally an afferent nerve, has a small motor root; but most of the motor fibres which answer to it are to be found in the Pneumogastric. That the Pneumogastric and Spinal Accessory together represent a Spinal nerve, may be regarded as probable from what has been already said of their relations.—Leaving these nerves out of the question, therefore, we proceed to the rest. Comparative anatomy, and the study of Embryonic development, alike show that the Spinal Cord and Medulla Oblongata constitute the most essential part of the nervous system in Vertebrata; and that the Cerebral Hemispheres are superadded, as it were, to this. At an early period of development, the Encephalon consists chiefly of four vesicles, which correspond with the ganglionic enlargements of the nervous cord of the Articulata, and mark four divisions of the Cerebro-Spinal axis; and, in accordance with this view, the Osteologist is able to trace, in the bones of the cranium, the same elements which would form four vertebræ, in a much expanded and altered condition.* The four pairs of nerves of special sensation,—Auditory, Gustatory, Optic, and Olfactory,—make their way out *through* these four cranial vertebræ respectively. At a later period of development other nerves are interposed *between* these; which, being *intervertebral*, are evidently more analogous to the Spinal nerves, both in situation and function. A separation of the primitive fibres of these takes place, however, during the progress of development, so that their distribution appears irregular. Thus the greater part of the sensory fibres are contained in the large division of the Trigeminus; whilst of the motor fibres, the anterior set chiefly pass forwards as the Oculo-motor and Patheticus; and of the posterior, some form the small division of the Trigeminus, and others unite with the first pair from the Medulla Oblongata to form the Facial. This last fact explains the close union, which is found in Fishes and some Amphibia, between that nerve and those proceeding more directly from the Medulla Oblongata. According to Valentin, the Glosso-pharyngeal is the sensory portion of the first pair from the Medulla Oblongata, of which the motor part is chiefly comprehended in the Facial nerve. Although we are accustomed to consider the Fifth pair as *par éminence* the Spinal nerve of the head, the foregoing statements, founded upon the history of development,† show that the nerves of the Orbit really belong to its motor portion; they may consequently be regarded as altogether forming the *first* of the *intervertebral* nerves of the cranium. The Facial and Glosso-pharyngeal appear to constitute the *second;* whilst the Par Vagum and Spinal Accessory, forming the *third* pair, intervene between this and the true Spinal, of which the Hypoglossal may be considered as the first.

501. *Functions of the Spinal Axis.*—In considering the functions of the Spinal Cord, we have to regard it under two aspects;—in the first place, as a *conductor* of nervous force between the Nerve-trunks and the Encephalic centres;—and in the second place, as itself *an independent centre* of nervous power. As a mere conductor of nervous force, its functions are the same as those of a nerve-trunk, for if it be divided, all the parts of the body which are solely supplied by nerves coming-off below the

* See Prof. Owen's "Archetype Skeleton;" and the Author's "Princ. of Gen. Phys."
† On this point, as well as on the functions of the Cephalic nerves generally, see Prof. Valentin "De Functionibus Nervorum Cerebralium et Nervi Sympathici," Bernæ, 1839.

point of section are completely paralyzed, as far as regards sensibility and voluntary movement; no impressions made upon them have the least power to affect the consciousness, and no exertion of the will is able to determine contraction of their muscles. This state of *paraplegia*, which may be experimentally induced in animals, is frequently witnessed in Man as a result of injury or of disease which seriously implicates the Spinal Cord; and as it has been shown that among the lower animals complete reunion of the Cord may take place after complete division, as indicated by the entire restoration of its functional powers and the complete redintegration of its structure,* so have we reason to believe that a similar regeneration may take place to a considerable extent in Man; this being marked by the gradual return of sensibility and power of voluntary movement in the lower limbs which had been at first completely paralyzed. This regeneration is of course less likely to occur in cases of disease, when the parts around are in an unhealthy state, than when the paralysis is due to injury, which all the restorative powers of the system are engaged in repairing; but it is to be remembered, that as the injuries which are likely to cause such lesions of the Cord, are nearly always attended with severe concussion (it being very rare for the Cord to be accidentally wounded by the penetration of a sharp instrument between the vertebræ, in the mode in which experiments are made upon animals), some of their first effects are attributable to the *shock* which it has sustained; so that the partial recovery which takes-place at an early period, must not be regarded as the result of regeneration of nervous tissue, which requires a much longer time for its completion.

502. The conducting power of the entire Spinal Cord being thus established, we have next to inquire whether any difference in endowment can be shown to exist in its several columns. By Sir C. Bell, it was supposed that the anterior columns possess the same endowments as the anterior roots of the nerves, and the posterior columns the same as the posterior roots; and this view is supported by the experiments of Longet,† who deduces from them the conclusion, that irritation of the *posterior* columns, as of the posterior nerve-roots, gives rise to excruciating pain, without exciting any other movements than such as are called into action in reflex respondence to the impression; and that irritation of the *anterior* columns excites movements directly (or without reflexion), and is not a source of pain. Again, he found that when the Spinal Cord was completely divided, and time was allowed for the reflex activity of the cord to subside (this disappearing rapidly in adult warm-blooded animals), the application of an electric current to the posterior columns of the separated part occasioned no muscular action whatever, whilst its transmission through the anterior columns called forth vigorous movements. Moreover, he states that the effects of the reversal of the electric current, transmitted through the anterior columns, were the same as those of the same reversal when the currents were transmitted through the anterior roots of the spinal nerves; whilst they differed from those

* See the admirable researches of M. Brown-Séquard, in "Gazette Médicale," 1849, No. 45, and 1850, No. 30; also the "Comptes Rendus de la Société de Biologie," 1849-1850.

† "Anatomie et Physiologie du Systême Nerveux," 1842, and "Traité de Physiologie," 1850, tom. ii. pp. 184-8.

produced by the same change in the direction of the currents, transmitted through a nerve of mixed endowments.—The researches of Van Deen * lead on the whole to the same conclusions; but they tend, in his opinion, to show that the conducting power both of the anterior and posterior columns is very imperfect, if their white strands be completely separated from their grey matter. His experiments appear to have conclusively established that the grey matter, as well as the white, possesses conducting powers; as we might indeed anticipate from the circumstance, that it contains a large amount of the fibrous form of nerve-tissue, and that the commissural connection between the two lateral halves of the Cord is established (according to Mr. J. L. Clarke, § 482) by its grey substance alone. That a ready transverse communication exists, is proved not merely by the fact that an impression made upon a nerve of one side will very commonly excite reflex movements on both; but also by the experiment of completely dividing one half of the cord as far as the median line, and dividing the other half to the same extent a short distance below the first section; for this operation does not interrupt the transmission of sensory impressions, although it seems doubtful whether motor influences can be thus propagated.†—The experimental results of Stilling,‡ again, are on the whole in harmony with the preceding; but he lays yet greater stress than Van Deen, on the importance of the grey matter to even the conductive power of the white.—These deductions, however, are strongly opposed by Longet; who affirms that he could never obtain any evidence either of sensibility or of motor power, on irritating the grey substance alone by the electric current; and that, on the other hand, the entire destruction of the grey matter for a considerable length, by means of a rod introduced into the interior of the Cord, did not seem in any degree to impair the conducting power of its columns.

503. It must be freely admitted, however, that there are numerous Pathological phenomena, which it is very difficult to reconcile with any of the foregoing conclusions regarding the relative functions of the anterior and posterior columns of the Spinal Cord: cases having been recorded, in which complete destruction of the anterior columns appeared to have taken place, without loss of voluntary motion in the parts below; whilst a similar destruction of the posterior columns has occurred, without corresponding lesion of sensibility.§ But it must be borne in mind that we are still far from having an accurate knowledge of the degree of structural change in the nervous centres, which is incompatible with the continued performance of their functions; and that there are instances in which

* "Traités et Découvertes sur la Physiologie et la Moëlle Epinière," Leide, 1841.

† A case is cited by Longet from Begin, in which a man was stabbed at the back of the neck, the point of the knife passing obliquely forwards between the sixth and seventh cervical vertebræ, dividing the antero-lateral and anterior columns of the Spinal Cord on the right side. He survived the injury six days; and suffered from complete paralysis of motion of the corresponding lower extremity, with incomplete paralysis of motion of the right arm, the sensibility remaining perfect. This case seems to show that the Will has no power to direct its motor impulses across the cord; since the parts deriving their nerves from the part of the cord below the partial section, were entirely withdrawn from its influence.

‡ "Untersuchungen über die Functionen des Rückenmarks und die Nerven," Leipzig, 1842.

§ See especially the case recorded by Mr. Stanley in "Med.-Chir. Transact.," vol. xxiii and by Dr. Webster, Op. cit., vol. xxvi.

the whole thickness of the cord has undergone softening and apparent disintegration, without the destruction of the functional connection between the Encephalon and the parts below the seat of the disease.*

504. It is no less difficult to reconcile with the experimental results already cited, those of other Physiologists, which appear to show that the anterior and posterior divisions of the Spinal Cord respectively minister to the motions of flexion and extension. This notion, which originated with Bellingeri,† was afterwards advocated by Valentin,‡ who inferred from his experiments, that if the *posterior* column of the Spinal Cord of the Frog be irritated at the point at which the nerves of either extremity are given-off, that extremity is *extended*, and that if the *anterior* column be irritated, the extremity is *flexed*, so that, since he admitted the anterior columns to be chiefly motor, and the posterior to be for the most part sensory, it would appear that the motor fibres of the extensors pass from the anterior into the posterior column, whilst those of the flexors are continued onwards in the anterior column. Confirmation of this inference was obtained by Valentin from experiments on Mammalia; and it is borne-out, in his opinion, by pathological phenomena observed in Man. According to this eminent physiologist, also, relaxation of the sphincters is analogous to the extended state of the extremities; and he has noticed a manifest relaxation of the sphincter ani in the frog, when the superior part of the spinal cord was irritated, so as to produce extension of the limbs. The experiments of Budge§ and Engelhart,‖ however, led them to an opposite conclusion; for it appeared to them that, in Mammalia, the nerve-fibres which act upon the *extensor* muscles are contained in the *anterior* columns, and those of the *flexor* muscles in the *posterior* columns; whilst, as regards the Frog, the nerve-fibres connected with the extensor muscles appeared to be situated posteriorly to those of the flexors. The experiments of Harless,¶ again, have led him to regard the *upper* part of the spinal cord in the Frog, between the 2nd and 4th vertebræ inclusive, as specially concerned in the *flexion* both of the anterior and posterior extremities, and the *lower* part, from the 5th to the 8th vertebræ inclusive, as in like manner concerned in their *extension*.—All these results can only at present be accepted as indicating that some such special arrangement of the nerve-fibres in the Spinal Cord, having reference to the combination of different muscular actions in groups, may have a real existence; there is far too little accordance, however, among the phe-

* See, for example, the case of 'Softening of the Spinal Marrow,' recorded by Dr. Nairne in the "Med.-Chir. Trans.," vol. xxxiv., in which a portion of the Cord at least an inch long, situated opposite the third and fourth dorsal vertebræ, was "so soft that the slightest pressure of the finger broke it up," being nearly in a fluid state through its whole thickness, yet the patient felt *pain* in his lower limbs, showing that the power of upward transmission remained, and although he had lost all Voluntary control over the muscles of the lower part of the body, yet they were affected with incessant *choreic* movements, which, as will be shown hereafter, Sect. 8, appears to originate in the Sensory Ganglia, and these movements were affected in such a marked manner by *emotions*, as plainly to indicate a *downward* transmission of motor power.

† "De Medullâ Spinali, nervisque ex eâ prodeuntibus," &c., Turin, 1823.

‡ "De Functionibus Nervorum Cerebralium et Nervi Sympathici," Bernæ, 1839.

§ "Untersuchungen über das Nervensystem," 1841.

‖ "Müller's Archiv.," heft 3, 1841.

¶ "Müller's Archiv.," 1846.

nomena described by different observers, to enable even a probable statement to be hazarded in regard to the nature of this arrangement; and it seems quite possible that it may vary in different animals, in accordance with their respective modes of progression. As far as Man is concerned, we have no evidence but that of pathological phenomena; and we certainly may find, in many forms of convulsive action, an indication that there is some common centre or tract of motor impulse for the extensor muscles generally, and another such centre or tract for the flexors.*

505. We have now to consider the Spinal Cord as an independent centre of nervous power, and to inquire whether the movements which are excited through its 'reflex' activity necessarily involve sensation. These movements are most characteristically displayed, when the Spinal Cord is cut-off from communication with the higher Nervous centres; probably rather because the nerve-force excited by the impression reacts through the Spinal ganglion to which it is conveyed, when it can no longer pass-on to the Encephalic centres (§ 469), than because (as some suppose) the impulse to reflex movement is ordinarily neutralized and rendered inoperative by an effort of the will. It is true that those reflex actions of the Spinal Cord which are necessary to the maintenance of Organic life, and which are equally performed whether the Spinal axis be in communication with the higher Encephalic centres or not, are continually modified or temporarily suspended by the Will; but this is only when we consciously bring the Will to bear upon them; and it is no less certain that we are *not* continually making any such exertions, in order to antagonize movements, which (as we learn from Pathological evidence), would be continually excited but for this neutralizing influence, if such a doctrine were correct.—The readiest demonstration of the independent power of the Spinal Cord, is derived from the motions exhibited by the limbs of animals, when irritation is applied to them after section of the Spinal Cord at some point above the entrance of their nerves; the fact that these movements are reflected through the Cord, and are not the product of direct stimulation applied to the part irritated, being shown by their complete cessation when the nerve-trunks are divided, or the substance of the Spinal Cord is broken-down. Thus, if a Frog be decapitated, its body remains supported on its limbs in the usual position, and will recover this if it be disturbed; irritation of the feet will cause it to leap; and tickling the cloaca with a probe will excite efforts to push away the instrument.† It is to be

* Thus in a case of Hysteric Paraplegia, which was for some time under the Author's observation, the extensors only of the limbs were paralysed, the will retaining its ordinary power over the flexors. And in ordinary Cramp, of which the patient just mentioned was subject to extremely severe attacks, the flexors alone are usually in action.

† It has been pointed-out by Messrs. Todd and Bowman, ("Physiological Anatomy," vol. i. p. 315), that the Spinal Cord of the male frog, at the season of copulation, naturally possesses a state of most extraordinary excitability. The thumb of each anterior extremity at this season, becomes considerably enlarged, as is well known to Naturalists. "This enlargement is caused principally by a considerable development of the papillary structure of the skin which covers it, so that large papillæ are formed all over it. A male frog, at this season, has an irrestible propensity to cling to any object, by seizing it between his anterior extremities. It is in this way that he seizes upon, and clings-to the female; fixing his thumbs to each side of her abdomen, and remaining there for weeks, until the ova have been completely expelled. An effort of the Will alone could not keep up the grasp uninter-

observed that a slight irritation applied to the peripheral *extremities* of the afferent nerves, is a more powerful excitor of reflex action, than a much stronger impression, which occasions acute pain, applied to their *trunks;* thus Mr. Grainger found that he could remove the entire hind leg of a Salamander with the scissors, without the creature moving or giving any expression of suffering, if the Spinal Cord had been first divided; yet that by irritation of the foot, especially by heat, in an animal similarly circumstanced, violent convulsive actions were excited in the legs and tail. This fact is important, not only as showing the comparatively powerful effect of impressions upon the cutaneous surface, but also as proving how little relation the amount of reflex action has to the intensity of sensation.

506. That the movements executed by the limbs of the lower animals when these are no longer connected by the Spinal Cord with the Encephalon, but remain in nervous connection with the Cord itself, do not take place through the intermediation of sensation, might be supposed to be sufficiently proved by the simple fact, that division of the Cord in Man, and hence by inference in the lower animals, reduces the parts below to a state of complete insensibility. But, on the other hand, the very performance, by decapitated animals of inferior tribes, of actions which had not been witnessed in Man under similar circumstances, has been held to indicate, that the spinal cord in them has an endowment which *his* does not possess. The possibility of such an explanation, however unconformable to that analogy throughout organized nature, which, the more it is studied, the more invariably is found to guide to truth, could not be disproved. Whatever experiments on decapitated animals were appealed-to, in support of the doctrine that the Encephalon contains the only seat of sensibility, could be met by a simple denial that the Spinal Cord is everywhere as destitute of that endowment, as it appears to be in Man. The cases of profound Sleep and Apoplexy might be cited as examples of reflex action without consciousness; but these have been met by the assertion, that in such conditions, sensations are *felt*, though they are not *remembered.* It is difficult, however, to apply such an explanation to the case of Anencephalous human infants (in which all the ordinary reflex actions have been exhibited, with an entire absence of brain), without supposing that the Medulla Oblongata is the seat of a sensibility which we know that the lower part of the Spinal Cord does not possess; and of this there is no evidence whatever.—Experiments on the lower animals, then, and observation of the phenomena manifested by apoplectic patients and anencephalous infants, *might* lead to the conclusion, that the Spinal Cord does not itself possess

ruptedly for so long a time; yet so firm is the hold, that it can with difficulty be relaxed. Whatever is brought in the way of the thumbs, will be caught by the forcible contraction of the anterior limbs; and hence we often find frogs clinging blindly to a piece of wood, or a dead fish, or some other substance which they may chance to meet with. If the finger be placed between the anterior extremities, they will grasp it firmly, nor will they relax their grasp until they are separated by force. If the animal be decapitated, whilst the finger is within the grasp of its anterior extremities, they still continue to hold-on firmly. The posterior half of the body may be cut-away, and yet the anterior extremities will still cling to the finger; but immediately that the segment of the Cord, from which the anterior extremities derive their nerves, has been removed, all their motion ceases. This curious instinct only exists during the period of sexual excitement; for at other periods the excitability of the anterior extremities is considerably less than that of the posterior.

sensibility, and that its reflex actions are independent of sensation. At this conclusion, Unzer, Prochaska, Sir G. Blane, Flourens, and other physiologists, had arrived; but it was not until special attention was directed to the subject by Dr. M. Hall, that facts were obtained by which a positive statement of it could be supported. For the question might have been continually asked,—If the Spinal Cord in Man be precisely analogous in function to that of the lower Vertebrata, why are not *its* reflex phenomena manifested, when a portion of it is severed from the rest by disease or injury? The answer to this question is twofold. In the first place, simple division of the cord with a sharp instrument leaves the separated portion in a state of much more complete integrity, and therefore in a state much more fit for the performance of its peculiar functions, than it ordinarily is after disease or violent injury; and as the former method of division is one with which the Physiologist is not likely to meet in Man as a result of accident, and which he cannot experimentally put in practice, the cases in which reflex actions would be manifested are likely to be comparatively few. But secondly, a sufficient number of such instances *have* now been accumulated, to prove that the occurrence is by no means so rare as might have been supposed; and that nothing is required but patient observation, to throw a great light on this interesting question, from the phenomena of disease. A most valuable collection of such cases, occurring within his own experience, has been published by Dr. W. Budd;* and the leading facts observed by him will be now enumerated.

507. In the first case, paraplegia was the result of angular distortion of the spine in the dorsal region. The sensibility of the lower extremities was extremely feeble, and the power of voluntary motion was almost entirely lost. "When, however, any part of the skin is pinched or pricked, the limb that is thus acted-on jumps with great vivacity; the toes are retracted towards the instep, the foot is raised on the heel, and the knee so flexed as to raise it off the bed; the limb is maintained in this state of tension for several seconds after the withdrawal of the stimulus, and then becomes suddenly relaxed." "In general, while one leg was convulsed, its fellow remained quiet, unless stimulus was applied to both at once." "In these instances, the pricking and pinching were perceived by the patient; but *much more violent* contractions are excited by a stimulus, of *whose presence he is unconscious*. When a feather is passed lightly over the skin, in the hollow of the instep, as if to tickle, convulsions occur in the corresponding limb, much more vigorous than those induced by pinching or pricking; they succeed one another in a rapid series of jerks, which are repeated as long as the stimulus is maintained." "When any other part of the limb is irritated in the same way, the convulsions which ensue are very feeble, and much less powerful than those induced by pricking or pinching." "Convulsions, identical with those already described, are at all times excited by the acts of defecation and micturition. At these times, the convulsions are much more vigorous than under any other circumstances, insomuch that the patient has been obliged to resort to mechanical means to secure his person while engaged in these acts. During the act of expulsion, the convulsions succeed one

* "Medico-Chirurgical Transactions," vol. xxii.

another rapidly, the urine is discharged in interrupted jets, and the passage of the fæces suffers a like interruption." The convulsions are more vigorous, the greater the accumulation of urine; and involuntary contractions occur whenever the bladder is distended, and also when the desire to relieve the rectum is manifested. "In all these circumstances, the convulsions are perfectly involuntary; and he is unable, by any effort of the will, to control or moderate them." The patient subsequently regained, in a gradual manner, both the sensibility of the lower extremities, and voluntary power over them; and as voluntary power increased the susceptibility to involuntary movements diminished, as did also their extent and power.—This case, then, exhibits an increased tendency to perform reflex actions, when the control of the brain was removed; and it also shows that a slight impression upon the *surface*, of which the patient was not conscious, was more efficacious in exciting reflex movements, than were others that more powerfully affected the sensory organs. It should be added that, in the foregoing case, the nutrition of the lower extremities was not impaired, as it is in most cases of paraplegia; the rationale of this phenomenon, which is to be constantly observed when the reflex actions of the part remain entire, will be understood by reference to §§ 358, 516.

508. In another case, the paralysis was more extensive, having been produced by an injury (resulting from a fall into the hold of a vessel) at the lower part of the neck. There was at first a total loss of voluntary power over the lower extremities, trunk, and hands; slight remaining voluntary power in the wrists, rather more in the elbows, and still more in the shoulders. The intercostal muscles did not participate in the movements of respiration. The sensibility of the hands and feet was greatly impaired. There were retention of urine, and involuntary evacuation of the fæces. Recovery took place very gradually; and during its progress, several remarkable phenomena of reflex action were observed. At first, tickling one sole excited to movement that limb only which was acted upon; afterwards, tickling either sole excited both legs; and on the 26th day, not only the lower extremities, but the trunk and upper extremities also. Irritating the soles, by tickling or otherwise, was at first the only method, and always the most efficient one, by which convulsions could be excited. From the 26th to the 69th day, involuntary movements in all the palsied parts continued powerful and extensive, and were excited by the following causes: in the lower extremities only, by the passage of flatus from the bowels, or by the contact of a cold urinal with the penis; convulsions in the upper extremities and trunk, attended with sighing, by plucking the hair of the pubes. On the 41st day, a hot plate of metal was applied to the soles, and was found to be a more powerful excitor of movement than any before tried. The movements continued as long as the hot plate was kept applied; but the same plate, at the common temperature, excited no movements after the first contact. Though the contact was distinctly felt by the patient, *no sensation of heat* was perceived by him, even when the plate was applied hot enough to cause vesication. At three different intervals, the patient took one-eighth of a grain of strychnia three times a day. Great increase of susceptibility to involuntary movements immediately followed, and they were excited by the slightest causes. No convulsions of the upper extre-

ations could ever be produced, however, by irritating their integument; though, under the influence of strychnia, pulling the hair of the head, or tickling the chin, would occasion violent spasmodic actions in them. Spontaneous convulsions of the palsied parts, which occurred at other times, were more frequent and more powerful after the use of strychnia. On the first return of voluntary power, the patient was enabled to restrain in some measure the excited movements; but this required a distinct effort of the will; and his first attempts to walk were curiously affected by the persistence of the susceptibility to excited involuntary movements. When he first attempted to stand, the knees immediately became forcibly bent under him; this action of the legs being excited by contact of the soles with the ground. On the 95th day this effect did not take place, until the patient had made a few steps; the legs then had a tendency to bend-up, a movement which he counteracted by rubbing the surface of the belly; this rubbing excited the extensors to action, and the legs became extended with a jerk. A few more steps were then made, the manœuvre was repeated, and so on. This susceptibility to involuntary movements from impressions on the soles, gradually diminished; and on the 141st day, the patient was able to walk about, supporting himself on the back of a chair which he pushed before him; but his gait was unsteady, and much resembled that of chorea. Sensation improved very slowly: it was on the 53rd day that he first slightly perceived the heat of the metal plate.—Now in this case, the abolition of common sensation was not so complete as in the former instance; but of the peculiar kind of impression, which was found most efficacious in exciting reflex movements, *no consciousness whatever was experienced.* Not less interesting was the circumstance, that convulsions could be readily excited by impressions on surfaces *above* the seat of injury: as, by pulling the hair of the scalp, a sudden noise, and so on. This proves two important points: first, that a lesion of the cord may be such as to intercept the transmission of voluntary influence, and yet may allow the transmission of that reflected from incident nerves. Secondly, that all influences from impressions on incident nerves are diffused through the cord; for, in the instance adduced, the reflected influence was undoubtedly not made to deviate into the cord by the morbid condition of that organ, but followed its natural course of diffusion, being rendered manifest in this case by the convulsions which were excited, in consequence of increased activity of the motor function of the cord. It is further interesting to remark, that, in the foregoing case, the reflex actions were very feeble during the first seven days, in comparison with their subsequent energy; being limited to slight movements of the feet, which could not always be excited by tickling the soles. (In another case of very similar character, it was three days after the accident, before any reflex actions could be produced.) It is evident, then, that the spinal cord must have been in a state of concussion, which prevented the manifestation of its peculiar functions, so long as this effect lasted; and it is easy, therefore, to perceive, that a still more severe shock might permanently destroy its power, so as to prevent the exhibition of any of the phenomena of reflex action.

509. So many cases of this kind have now occurred, that it may be considered as a demonstrated fact, that the Spinal Cord, or insulated

portions of it, may serve in Man, no less than in the lower animals, as the centre of very energetic reflex actions, when the Encephalic power which ordinarily operates through it is suspended or destroyed, or when it is prevented from influencing the Spinal nerves by such an injury to the Cord above their points of connection with it, as prevents the transmission of nervous polarity and it is further evident that these movements are not more dependent upon Sensation, than they are upon the Will, since they may be excited without the consciousness of the individual, even when this is fully directed to the part.* And we thus have adequate ground for the assertion, that the movements which may be called-forth by stimulation in the states of profound Sleep or Coma, are not to be held to indicate that sensation is even momentarily excited; since we know that the reflex power of the Spinal Cord may be called into action by impressions which do not travel onwards to the sensorium, or which are powerless to affect the consciousness even when they arrive there. These abnormal reflex actions of the Spinal Cord of Man though often powerful, have much less regularity and apparent *purposiveness* than have the movements executed by the lower Vertebrata (as the Frog, § 505) after decapitation or section of the cord; the latter approaching, in respect to these qualities, to the reflex movements of Articulated animals. It must not hence be inferred, however, that there is any essential difference in the endowments of the Spinal Cord, between Man and the lower animals; or that any *psychical* agency exists in the latter case, which is wanting in the former. We have already seen that the existence of even the most perfectly-adapted combination of different muscular actions, all obviously bearing upon a definite object, cannot in itself justify our attributing this combination to design or voluntary choice on the part of the organism that executes it (§ 459); whilst, on the other hand, to remove these movements in any case from the category of *automatic* actions, would be to assign to the Spinal Cord a power of consciously selecting and directing them, such as we have every reason for believing to be limited to the higher parts of the Cerebro-spinal centres. Now the very *uniformity* of the movements in question, is itself an indication that they do *not* proceed from any purposive choice, but depend upon the special endowments of those centres of reflex action, whence the impulses that call them forth immediately issue to the nerves; and hence the more marked adaptiveness of the reflex actions performed by many of the lower tribes of animals, can only be held to indicate that a larger share of such adaptation is effected in them by what may be termed the *mechanism* of their nervous centres, and that less is left to voluntary choice and direction, which can only be safely trusted where a considerable amount of intelligence exists to guide it;— a conclusion which accords well with what has been already stated respecting the structural differences that seem to exist between the Spinal Cord of Man, and that of the inferior Vertebrata (§ 487).

* The Author is informed by his friend Mr Paget, that among the notes left by John Hunter (which furnished some of the materials for the admirable Catalogue of the Pathological portion of the Hunterian Museum drawn up by Mr Paget), there was the record of a case of paraplegia, in which it appeared that Hunter had witnessed reflex movements of the legs in which sensation did not participate. When the patient was asked whether he felt the irritation by which the motions were excited, he significantly replied, glancing at his limbs,—"No, Sir, but you see *my legs* do."

510. The endowments of the *Medulla Oblongata* do not seem to differ from those of the Spinal Cord in any other respect, than in the speciality of the reflex movements to which it ministers. This part of the Cranio-Spinal Axis has been regarded by some Physiologists, indeed, as the peculiar seat of vitality; since, although the other Encephalic masses may be withdrawn from above, and nearly the whole of the Spinal Cord may be removed from below, without the destruction of life, yet a complete stop is put to the current of vital action when the Medulla Oblongata is destroyed. But the dependence of the vital activity of the body generally upon the functional integrity of this part of the nervous system, is simply consequent upon the fact, that the Medulla Oblongata contains the ganglionic centre of the Respiratory movements; upon the continuance of which, as already shown (Chap. VII. Sect. 3), the continuance of the Circulation is dependent, and with this, the maintenance of the Organic functions generally. It is also the ganglionic centre of the nerves of Deglutition; the abolition of which function must of course be destructive to life, though less speedily than that of Respiration.

511. Hence the Spinal Cord, with its Encephalic prolongation, may be said to supply, by its 'reflex power,' *the conditions requisite for the maintenance of the various muscular movements which are essential to the continuance of the Organic processes;* and, as Dr. M. Hall has pointed out, it especially governs the various orifices of ingress and egress.—Thus, the act of Deglutition is entirely dependent upon the Spinal Axis and the nerves proceeding from it; the Will being in no other way concerned in it, than by originating the necessary stimulus; and even sensation not being a necessary link in the chain of excito-motor action (§§ 80—82). The action of the cardiac sphincter, again,—and probably that of the pyloric sphincter also,—is dependent upon its nervous connection with the Spinal Axis; and is entirely regulated without sensorial excitement (§ 82). And there is much reason to believe that certain of the movements of the Stomach itself are in like manner dependent upon its connection with the Medulla Oblongata (§ 84), although there is evidence that it possesses an independent motor activity of its own. The movements of the Intestinal tube are unquestionably influenced by the Spinal Cord, although essentially independent of it (§§ 86, 87); but the sphincter which surrounds its orifice of egress is undoubtedly placed under its guardianship, although partly subjected (in Man) to the control of the Will. The same may be said of the *expulsor* muscles concerned in the act of Defecation; and of the expulsors and sphincter which effect and control the act of Urination (§ 88).—Looking, again, at the movements which are subservient to the Respiratory process, we find that all those which are essential to its regular maintenance are performed through the intermediation of the Spinal Axis alone; that the Will has only such a limited power over them, as to bring them into harmony with its other requirements, as in the acts of vocalization and in extraordinary muscular exertions; and that the stimulus by which they are commonly maintained does not even affect the consciousness, the 'besoin de respirer' only becoming *sensible* when the respiratory process is being imperfectly performed (§§ 299—302). Not only are the ordinary respiratory movements performed through this channel, but the aperture of the Glottis is regulated by it, in everything that

concerns the respiration; and either by its spasmodic closure against the entrance of unfit substances, or by the expulsor effort of coughing which is excited by them when they do find their way into the air-passages, these passages are kept free from solid, liquid, or gaseous particles whose presence in them would be injurious.—In the expulsion of the Generative products, also, the reflex power of the Spinal Cord takes an important share. The muscular contractions which produce the Emission of Semen are excito-motor in their nature; being independent of the Will, and not capable of restraint by it when once fully excited, and being (as those of Deglutition) excitable in no other way than by a particular local irritation. It has been shown by experiment, and also by pathological observation, that the separation of the lower portion of the Spinal Cord from the upper does not prevent these movements from being excited, although the act is then unaccompanied with sensation, which proves that sensation is not essential to its performance; on the other hand, the power of emission is annihilated by destruction of the lower portion of the Spinal Cord, or by section of the nerves which supply the genital organs. The act of Parturition, however, seems to be less dependent upon the Spinal Cord; for, as will be shown hereafter (Chap. XVI., Sect. 3), the contractions of the Uterus, which are alone sufficient to expel the fœtus when there is no considerable resistance, are not to be regarded as 'reflex;' and it is only in the co-operation of those associated muscles which come into play in the second stage of labour, when the head is passing through the os uteri and is engaged in the pelvic cavity, that the assistance of the Spinal cord and its nerves is called-in. These movements, like those of Defecation, may be to a certain extent promoted or restrained by voluntary effort, but when the exciting influence (the pressure of the head against the parietes of the vaginal canal) has once been fully brought into operation by the uterine contractions, the Will has little power over them, either in one way or the other. The antagonizing influence of the sphincter vaginæ seems, like that of the sphincter ani, to be dependent upon the Spinal Cord; and thus it happens that when its tension and that of other muscular parts has been destroyed by death, whilst the uterus still retains its contractility, the power of the latter has sufficed for the completion of the parturient process, the child being expelled after the respiratory movements have ceased.

512. The Spinal Axis is not merely the instrument whereby the movements essential to the maintenance of the Organic functions are sustained; it is also subservient to other muscular actions, whose character is essentially *protective*. Thus it was ascertained by Dr. M. Hall* that, if the functions of the Brain be suspended or destroyed, without injury to the Spinal Cord and its nerves, the Orbicularis muscle will contract, so as to occasion the closure of the eyelids, upon their tarsal margin being touched with a feather. This fact is interesting in several points of view. In the first place, it is a characteristic example of an adaptive action, occurring under circumstances in which volition cannot be imagined to guide it, and in which there is no valid reason to believe that sensation directs it. Further, it explains the almost irresistible nature of the tendency to winking, which is performed at short intervals

* "Memoirs on the Nervous System," 1837, p. 61.

by the contraction of the Orbicularis muscle; this is evidently a reflex action, capable of being in some degree restrained (like that of respiration) by the will, but only until such time as the stimulus (resulting perhaps from the collection of minute particles of dust upon the eyes, or from the dryness of their surface in consequence of evaporation,) becomes too strong to be any longer resisted. The nervous channel through which this action is performed, is completed by the first branch of the Fifth and the Portio Dura of the seventh. Again, we have in sleep or in apoplexy an example of this purely spinal action, unbalanced by the influence of the will, which, in the waking state, antagonizes it by calling the levator palpebræ into action. As soon as the will ceases to act, the lids droop, and close over the eye so as to protect it; and if those of a sleeping person be separated by the hand, they will be found presently to return. Here, as in studying the respiratory and other movements, we are led to perceive that it is the Brain alone which is torpid during sleep, and whose functions are affected by this torpidity. As Dr. M. Hall very justly remarks, "the Spinal system never sleeps;" it is constantly in activity; and it is thus that, in all periods and phases of Life, the movements which are essential to its continued maintenance are kept-up without sensible effort.—The closure of the pupil against a strong light, is another movement of the same protective tendency. The contraction of the pupil is immediately caused by the Third pair, or Motor Oculi, as is easily shown by irritating the trunk of that nerve and observing the result; but the stimulus which excites it is conveyed through the Optic nerve. Yet although the contraction of the pupil is usually in close accordance with the *sensation* occasioned by the impression of light upon the retina, yet there is evidence to prove that the sensation of light is not always necessary: for even when the sight of both eyes has been entirely destroyed by amaurosis, the normal actions have been witnessed in the pupil, in accordance with the varying degrees of light impinging on the retina. Such cases seem to indicate that the motion results from an *impression* upon the retina, which impression being conducted to the Sensorium, ordinarily produces a sensation; but that even where no sensation is produced, on account of a disordered state of the part of the ganglionic centre in which the Optic nerve terminates, if the central tract which connects that nerve with the Third pair retain its integrity, the reflex contraction of the pupil may still be excited through it. The rarity of the occurrence is easily accounted-for, by the fact that in most cases of amaurosis, the disease lies in the retina or in the trunk of the nerve, and thereby checks both its spinal and its encephalic actions. —Although we are not at present acquainted with any similar protective movements, in the Human being, designed to keep the organ of Hearing from injury, yet there can be little doubt that those which we are constantly witnessing in other animals, possessed of large external ears, are reflex actions excited by the irritation applied to them. In regard to the Nose, we find a remarkably complex action—that of Sneezing—adapted to drive-off any cause of irritation (§ 306). The stimulus is conveyed, in this case, not through the Olfactory nerve, but through the Fifth pair; so that it is not dependent upon the excitement of the sensation of Smell. The act of Coughing, also, may be regarded as of a protective character, being destined to remove sources of irritation from the air-passages.

Many of the automatic movements performed by the limbs of Frogs and other animals, when their connection with the brain has been cut off (§ 505), appear destined to remove these parts from sources of irritation or injury; and they may thus be rightly placed under the same category.

513. The fact that Sensation is very commonly *associated with* the reflex actions we have been considering, being produced by the impression that excites them, has led many to suppose that it necessarily participates in them,—a doctrine which we have seen to be untenable. But the question not unnaturally arises, *why* Sensation should so constantly participate in these operations, if not essential to them, and the answer to this question is to be found in the fact, that it is only through sensation that a higher set of actions, mental and bodily, is called into play which is essential to the *continued maintenance* of those belonging to the present category. Illustrations of this truth might be drawn from any of the functions already noticed; but the Ingestion of food will supply us with one of the most apposite. We have seen that the act of Deglutition is in itself independent of sensation; anything that comes within the grasp of the pharyngeal constrictors being conveyed downwards by their reflex contraction, just as anything which touches the arms of a Polype is entrapped by them and drawn into the stomach. But this action is attended with sensation, in the ordinary condition of the higher Animal, apparently in order that guidance may be thus afforded in the performance of those other movements of prehension, mastication, &c., by which the food may be brought within reach of the apparatus of deglutition; and the sensations which are linked with these, are among the influences which prompt to those higher mental operations, whereby food is provided for the digestive apparatus to make use of. The Zoophyte is dependent for its supplies of aliment, upon what the currents in the surrounding fluid, or other chances, may bring into its neighbourhood; and if these should fail, it starves. The anencephalous Infant, again, can swallow, and even suck; but it can execute no other movements adapted to obtain the supply of food continually necessary for its maintenance, because it has not a mind which sensations could awake into activity. The sensation connected with excito-motor actions has not only this important end, but it frequently contributes to enjoyment, as in Suction and Ejaculatio seminis. The sensation accompanying the actions of this class, moreover, frequently affords premonition of danger, or gives excitement to supplementary actions destined to remove it, as in the case of Respiration; for where anything interferes with the due discharge of the function, the uneasy sensation that ensues occasions unwonted movements, which are more or less adapted to remove the impediment, in proportion as they are guided by judgment as well as by consciousness. Again, sensation often gives warning against inconvenience, as in the Excretory functions; and here it is very evident that its purpose is not only (if it be at all) to excite the associated muscles necessary for the excretion, but actually to make the Will set up the antagonizing action of the sphincters (§§ 88, 89).

514. We have now to inquire how far the independent action of the Spinal Cord is concerned in the general muscular movements of Man and especially in the locomotive actions of his inferior extremities. On

this point, it is obvious that we must not be guided by the analogy of the lower animals, since the locomotive and other movements of Man are for the most part volitional and purposive, and he has to acquire by experience that control over his muscular apparatus which is necessary to enable him to perform them; whilst in Invertebrata generally, and in a large part of the lower Vertebrata, it is evident that the movements of progression, &c. which are characteristic of each species, come under the general category of automatic actions, and are provided-for in the original organization of its nervous centres, being performed without any education, and under circumstances which render the notion of a purpose on the Animal's own part quite untenable. In so far as these instinctive movements require the guidance and direction of sensations, they must be referred to the 'consensual' group; but clear evidence is afforded by the continuance of many of them after the removal of the centres of sensation, that they are excito-motor in their character, and that they require no higher centre, than the ganglia which correspond to the Spinal Cord of Man.* There can be little doubt that the habitual movements of locomotion, and others which have become 'secondarily automatic,' may be performed by Man (under particular circumstances) through the agency of the Spinal Cord alone, under the guidance and direction of the Sensorial centres, or even without such guidance; the required condition being, that the influence of the Cerebrum shall be entirely withdrawn. Thus, numerous instances are on record, in which soldiers have continued to *march* in a sound sleep; and the Author has been assured by an intelligent witness, that he has seen a very accomplished pianist complete the performance of a piece of music in the same state.† A case has been mentioned to him by his friend Dr William Budd, of a patient labouring under that form of epilepsy in which there was simply a temporary suspension of consciousness without convulsion, who, whenever the paroxysm came on, persisted in the kind of movement in which he was engaged at the moment; and thus on one occasion fell into the water through continuing to walk onwards, and frequently (being a shoemaker by trade) wounded his fingers with the awl in his hand, by a repetition of the movement by which he was endeavouring to pierce the leather. Such facts as these add great strength to the probability, that when the Cerebral power is not suspended, but merely directed into another channel, as in the states of Reverie or Abstraction, and the attention is entirely drawn-off from the movements of locomotion, the continuance of these is due to the independent automatic action of the Spinal Cord, the *direction* being given to them by the Sensory Ganglia. This point, however, will be more fully considered hereafter (§ 540), at present it may be remarked, that, when a regular train of movements is being performed under such conditions, every single action may be probably regarded as affording the stimulus to the next; each contact of the foot with the ground, in the act of walking, exciting the muscular contractions which constitute the

* See "Princ. of Comp. Phys.," §§ 649–654.

† In playing by memory on a musical instrument, the *muscular* sense often suggests the sequence of movements with more certainty than the *auditory*, and since the impressions derived from the muscles may prompt and regulate successional movements, without affecting the consciousness, there is no such improbability in the above statement as might at first sight appear.

next step;* and each movement of the musician prompting that which has customarily followed it, after the same fashion.

515. Now in all these cases, it seems reasonable to infer, that the same kind of connection between the excitor and motor nerves comes to be formed by a process of gradual development, as originally exists in the nervous systems of those animals whose movements are entirely automatic; this portion of the nervous system of Man being so constituted, as to *grow-to* the mode in which it is habitually called into play. Such an idea is supported by all that we know of the formation and persistence of *habits* of nervo-muscular action. For it is a matter of universal experience, that such habits are far more readily acquired during the periods of infancy, childhood, and youth, than they are after the attainment of adult age; and that, the earlier they are acquired, the more tenaciously are they retained. Now it is whilst the organism is growing most rapidly, and the greatest amount of new tissue is consequently being formed, that we should expect such new connections to be most readily established; and, it is then, too, that the assimilative processes most readily take-on that new mode of action (§ 346), which often becomes so completely a 'second nature,' as to keep-up a certain acquired mode of nutrition through the whole subsequent life. It is an additional and most important confirmation of this view, to find that when a nerve-trunk has been cut-across, the re-establishment of its conductive power which takes-place after a certain interval, is not effected by the re-union of the divided fibres, but by the *development* of a new set of peripheral fibres in the place of the old ones (which undergo a gradual degeneration), this development proceeding from the point of section, and the central fibres remaining unaltered.†—That an actual continuity of nerve-fibres, however, is not requisite for the establishment of those connections between excitor and motor nerves, in which the central organs take part, seems probable from the fact, that under particular circumstances we find the influence of such impressions radiating in every direction, and extending to nerves which they do not ordinarily affect (Sect. 8). Still there can be no doubt that the nerve-force is disposed to pass in special *tracks;* and it seems probable that whilst some of these are originally marked-out for the automatic movements, others may be gradually worn-in (so to speak) by the habitual action of the Will; and that thus, when a train of sequential actions primarily directed by the Will has been once set in operation, it may continue without any further influence from that source.

516. Another manifestation of the independent power of the Spinal Cord, is seen in its influence on *Muscular Tension.*—The various muscles of the body, even when there is the most complete absence of effort, maintain in the healthy state of the system, a certain degree of firmness, by their antagonism with each other; and if any set of muscles be completely paralyzed, the opposing muscles will draw the part on which they act, out of its position of repose; as is well seen in the distortion of the

* The truth of this view seems to the Author to be strongly supported by observation of the mode in which Infants learn to walk; for it may often be observed that long before they can stand, they will instinctively perform the movements of walking, if they be so supported that the feet touch the ground.

† See Dr. Waller's important researches on the Reproduction of Nervous Substance, in "Muller's Archiv.," 1852, heft iv.

ace which is characteristic of paralysis of the facial nerve on one side. This condition has been designated as the *tone* of the Muscles; but this term renders it liable to be confounded with their *tonic contraction*, which is also concerned in maintaining their firmness, but which is a manifestation of the simple contractility of their tissue, and is exhibited alike by the striated and the non-striated forms of muscular fibre, but more especially by the latter. (See PRINC. OF GEN. PHYS.) On the other hand, the condition now alluded-to, which may perhaps be appropriately termed their *tension*, is the result of a moderate though continued excitement of that contractility, through the nervous centres. It has been proved by Dr. M. Hall, that the Muscular Tension is dependent, not upon the influence of the Brain, but upon that of the Spinal Cord, as the following experiments demonstrate.—"Two Rabbits were taken; from one the head was removed; from the other also the head was removed, and the spinal marrow was cautiously destroyed with a sharp instrument: the limbs of the former retained a certain degree of firmness and elasticity; those of the second were perfectly lax." Again: "The limbs and tail of a decapitated Turtle possessed a certain degree of firmness or tone, recoiled on being drawn from their position, and moved with energy on the application of a stimulus. On withdrawing the spinal marrow gently out of its canal, all these phenomena ceased. The limbs were no longer obedient to stimuli, and became perfectly flaccid, having lost all their resilience. The sphincter lost its circular form and contracted state, becoming lax, flaccid, and shapeless. The tail was flaccid, and unmoved on the application of stimuli."* It is further remarked by Messrs. Todd and Bowman, that "a decapitated frog will continue in the sitting posture through the influence of the spinal cord; but immediately this organ is removed, the limbs fall apart."—This operation of the Spinal Cord is doubtless but a peculiar manifestation of its ordinary reflex function. We shall hereafter see (§ 541) how much the influence of the Will in producing the active contraction of a muscle, is dependent upon sensations received from it; and it seems highly probable, that the impression of the state of the muscle, conveyed by the afferent fibres proceeding from it to the spinal cord, is sufficient to excite this state of moderate tension through the motor nerves arising from the latter. Such a view derives probability from the fact, which must have fallen under the observation of almost every one, that most reflex actions become increased in energy, if resistance be made to them. Of this we have familiar examples in the action of the expulsor muscles, which operate in defecation, urination, and parturition, if, when they are strongly excited, their efforts be opposed by spasmodic contraction of the sphincters, or by mechanical means. Many forms of convulsive movement exhibit the same tendency, their violence being proportional to the mechanical force used to restrain them.† Here it is evident that the *impression of resistance*, conveyed to the Spinal Cord, is the source of the increased energy of its motor influence, from which we may fairly infer that the moderate resistance,

* "Memoirs on the Nervous System," 1837, p. 93.

† Hence the absurdity of the common practice of endeavouring to *prevent* the movements of the convulsed body, in Convulsive paroxysms, by mechanical constraint. Nothing should be attempted, but what is requisite to guard the sufferer from doing himself an injury.

occasioned by the natural antagonism of the muscles, is the source of their continued and moderate tension, whilst they are under the influence of the Spinal Cord. This constant though gentle action serves to keep-up the nutrition of the muscles, which are paralyzed to the will; and this is still more completely maintained, if the portion of the nervous centres, with which they remain connected, be so unduly irritable that the muscles are called into contraction upon the slightest excitation, and are thus continually exhibiting twitchings, startings, or more powerful convulsive movements. It is upon the continuance of the nutrition of the muscles, that the persistence of their contractility depends; and hence the Spinal Cord has an indirect influence upon this peculiar property, which is more likely to be retained, when the muscle is still subject to the influence of the Spinal Cord, though cut-off from that of the Brain, than when it is completely paralyzed by the entire separation of its connection with the nervous centres.

3. *Of the Sensory Ganglia and their Functions.—Consensual Movements.*

517. At the base of the Brain in Man, concealed by the Cerebral Hemispheres, but still readily distinguishable from them, we find a series of ganglionic masses; which are in direct connection with the nerves of Sensation, and which appear to have functions quite independent of those of the other components of the Encephalon.—Thus anteriorly we have the *Olfactive* ganglia, in what are commonly termed the 'bulbous expansions of the Olfactive nerve.' That these are real ganglia, is proved by their containing grey or vesicular substance; and their separation from the general mass of the Encephalon, by the peduncles or footstalks commonly termed the 'trunks' of the Olfactory nerves, finds its analogy in many species of Fish. The ganglionic nature of these masses is more evident in many of the lower Mammalia, in which the organ of Smell is highly developed, than it is in Man, whose olfactive powers are comparatively moderate.—At some distance behind these, we have the representatives of the *Optic* ganglia, in the Tubercula Quadrigemina, to which the principal part of the roots of the Optic nerve may be traced. Although these bodies are so small in Man, in comparison with the whole Encephalic mass, as to be apparently insignificant, yet they are much larger, and form a more evidently-important part of it, in many of the lower Mammalia; though still presenting the same general aspect. The *Auditory* ganglia do not form distinct lobes or projections, but are lodged in the substance of the Medulla Oblongata. Their real character is most evident in certain Fishes, as the Carp; in which we trace the Auditory nerve into a ganglionic centre as distinct as the Optic ganglion. In higher animals, however, and in Man, we are able to trace the Auditory nerve into a small mass of vesicular matter, which lies on each side of the Fourth Ventricle, and although this is lodged in the midst of parts whose function is altogether different, yet there seems no reason for doubting that it has a character of its own, and that it is really the ganglionic centre of the Auditory nerve.—In like manner, we may probably fix upon a collection of vesicular matter, imbedded in the Medulla Oblongata,—which is considered by Stilling to be the nucleus of the Glosso-pharyngeal nerve, and to which a portion of the

sensory root of the Fifth pair may be also traced,—as representing the *Gustatory* ganglion.

518. At the base of the Cerebral Hemispheres, we find two other large ganglionic masses on either side, through which nearly all the fibres appear to pass, that connect the Hemispheres with the Medulla Oblongata: namely, the *Thalami Optici*, and the *Corpora Striata*. Now, although these are commonly regarded in the light of appendages merely to the Cerebral Hemispheres, it is evident from the large quantity of vesicular matter they contain, that they must rank as independent ganglionic centres; and this view is supported alike by the evidence of Comparative Anatomy, and by that afforded by the history of Development. For it is certain that the size of the Thalami Optici and Corpora Striata presents no more relation, in different tribes of animals, to that of the Cerebrum, than does that of the ganglia of Special Sense; and they may even present a considerable development, when the condition of the Cerebrum is quite rudimentary. Thus in the Osseous Fishes, a careful examination of the relations of the body which is known as the Optic lobe (Fig. 80, C) makes it apparent that this is the representative, not merely of the proper Optic ganglion of Man, but also of the Thalamus Opticus; whilst, again, the mass which is designated as the Cerebral lobe (B) is chiefly homologous with the Corpus Striatum of higher animals. The nature of the latter body is made apparent, in the higher Cartilaginous Fishes, by the presence of a ventricle in its interior, the floor of this cavity being formed by the Corpus Striatum, whilst the thin layer of nervous matter which forms its roof is the only representative of the Cerebral hemisphere. So in the Human embryo of the 6th week, we find a distinct vesicle for the Thalami Optici, interposed between the vesicle of the Corpora Quadrigemina and that which gives origin to the Cerebral Hemispheres, whilst the Corpora Striata constitute the floor of the cavity or ventricle which exists in the latter, this being as yet of comparatively small dimensions.—Now, as already pointed out (§ 490), we may distinguish in the Medulla Oblongata and Crura Cerebri, a *sensory* and a *motor* tract; by the endowments of the nerves which issue from them. The sensory tract may be be traced upwards, until it almost entirely spreads itself through the substance of the Thalamus. Moreover, the Optic nerves, and the peduncles of the Olfactive, may be shown to have a distinct connection with the Thalami; the former by the direct passage of a portion of their roots into these ganglia; and the latter through the medium of the Fornix. Hence we may fairly regard the *Thalami Optici* as the chief focus of the *Sensory* nerves, and more especially as the ganglionic centre of the nerves of *common* sensation, which ascend to it from the Medulla Oblongata and Spinal Cord.—On the other hand, the *Corpora Striata* are implanted on the *Motor* tract of the Crura Cerebri, which descend into the Pyramidal columns; and their relation to the fibres of which that tract is composed, appears to be essentially the same as that which the Thalami bear to the sensory tract. The Corpora Striata are connected with each other, on the median plane, by the *anterior* commissure; and the Thalami Optici, by the *soft* and the *posterior* commissures. The Corpus Striatum and Thalamus Opticus of the same side are very closely connected by commissural fibres, stretching from one to

the other; and, if the preceding account of the respective offices of these bodies be correct, they may be regarded as having much the same relation to each other, as that which exists between the posterior and anterior peaks of vesicular matter in the Spinal Cord,* the latter issuing motor impulses, in respondence to sensations excited through the former. They are also intimately connected with other ganglionic centres in their neighbourhood, such as the 'locus niger,' and the vesicular matter of the 'tuber annulare'; which, again, are in close relation with the vesicular matter of the Medulla Oblongata.

519. It has been commonly supposed that the fibres of the Crura Cerebri, after entering the Corpora Striata and Thalami Optici, pass continuously through these bodies, receiving 'reinforcements' of additional fibres from their ganglionic matter; and that they then radiate to the internal surface of the grey matter of the Cerebral Hemispheres. Such would certainly be the conclusion, to which a superficial examination of their course would lead. But very strong reasons have recently been advanced for the belief, that the fibres of the Crura Cerebri for the most part, if not entirely, terminate in the vesicular substance of the Corpora Striata and Thalami Optici, and that the radiating fibres of the Hemispheres take a fresh departure from these ganglia, serving, in fact, the part of commissures to connect *their* vesicular substance with that of the Cerebral ganglia.† And this view, as we shall hereafter see, is in complete accordance with the existence of a very decided *physiological* separation between these two sets of organs.—Altogether it is very evident, that a series of true ganglionic centres exists at the base of the Encephalon, which are really as distinct from either the Cerebrum or Cerebellum, as the latter are from each other; and as these centres are in immediate connection with the nerves both of *special* and of *general* Sense, they may be appropriately designated the *Sensory Ganglia*. —An inquiry into the distribution and endowments of their nerves, will assist us in the determination of the functions of the central organs in which they terminate.

520. *Nerves of Special Sense.*—Through the First pair, or *Olfactory* nerve, are transmitted the impressions made by odorous emanations upon the surface it supplies; and it is not susceptible to impressions of any other kind. Anatomical examination of the distribution of this nerve proves that it is not one which directly conveys motor influence to any muscles, since all its branches are distributed to the membrane lining the nasal cavity; and experimental inquiry leads to the same result, for no irritation of the peduncles or branches excites any muscular movement. Further, no irritation of any part of this nerve excites reflex actions through other nerves. Again, it is not a nerve of 'common' sensation; for animals exhibit no signs of pain, when it is subjected to any kind of irritation. Neither the division of the nerve, nor the destruction of the olfactive ganglia, seems to inconvenience them materially. They take their food, move with their accustomed agility, and exhibit the usual appetites of their kind. The 'common' sensibility of

* This was first pointed out by Messrs. Todd and Bowman, in their "Physiological Anatomy," vol. i. pp. 347-350.

† See especially Messrs. Todd and Bowman's "Physiological Anatomy," vol. i. p. 277 and Prof. Kolliker's "Mikroskopische Anatomie," band ii., § 115.

the parts contained in the olfactive organ is in no degree impaired, as is shown by the effect of irritating vapours; but the animals are destitute of the sense of smell, as is shown by the way in which these vapours affect them; for at first they appear indifferent to their presence, and then suddenly and vehemently avoid them, as soon as the Schneiderian membrane becomes irritated. Moreover, if two dogs, with the eyes bandaged, one having the olfactory nerves and ganglia sound, and the other having had them destroyed, are brought into the neighbourhood of the dead body of an animal, the former will examine it by its smell; whilst the latter, even if he touches it, pays no attention to it. This experiment Valentin* states that he has repeated several times, and always with the same results. Further, common observation shows that *sensibility to irritants*, such as snuff, and *acuteness of smell*, bear no constant proportion to one another; and there is ample pathological evidence, that the want of this sense is connected with some morbid condition of the olfactory nerves or ganglia.—It is well known that Magendie has maintained, that the Fifth pair in some way furnishes conditions requisite for the exercise of the power of smell; asserting that, when it is cut, the animal is deprived of this sense. But his experiments were made with irritating vapours, which excite sternutation or other violent muscular actions, not through the Olfactory nerve, but through the Fifth pair: and the experiments of Valentin, just related, fully prove that the animals are not sensitive to *odours*, strictly so called, after the Olfactory nerve has been divided. The acuteness of the true sense of smell is lessened by section of the Fifth pair; but this is because the Schneiderian membrane is then no longer duly moistened by its proper secretion, and, when dry, it is less susceptible of the impressions made by those minute particles of odoriferous substances, to which the excitement of the sensation must be referred.

521. That the Second pair, or *Optic* nerve, has an analogous character, appears alike from anatomical and experimental evidence. No chemical or mechanical stimulus of the trunk produces *direct* muscular motion; nor does it give rise, so far as can be ascertained, to indications of pain; whence it may be concluded, that this nerve is not one of 'common' sensation. That the ordinary sensibility of the eyeball remains, when the functions of the Optic nerve are completely destroyed, is well known; as is also the fact, that division of it puts an end to the power of vision. Valentin states that, although the Optic nerve may, like other nerves, be in appearance completely regenerated, he has never been able to obtain any evidence that the power of sight has been in the least degree recovered. He remarks that animals suddenly made blind exhibit great mental disturbance, and perform many unaccustomed movements; and that the complete absence of the power of vision is easily ascertained. Morbid changes are sometimes observed to take place in eyes, whose Optic nerve has been divided; but these are by no means so constant or so extensive, as when the Fifth pair is paralysed; and they may not improbably be attributed to the injury occasioned by the operation itself, to the parts within the orbit.

522. The Optic nerve, though analogous to the Olfactory in all the

* "De Functionibus Nervorum Cerebralium," &c., Bernæ, 1839.

points hitherto mentioned, differs from it in one important respect,—that it has the power of conveying impressions which excite *reflex* muscular motions. This is especially the case in regard to the Iris, the ordinary actions of which are regulated by the degree of light impinging on the retina. When the Optic nerve is divided, contraction of the pupil takes place; but this does not occur, if the connection of this nerve with the third pair, through the nervous centres, be in any way interrupted. After such division (if complete), the state of the pupil is not affected by variations in the degree of light impinging on the retina; except in particular cases, in which it is influenced through other channels. Thus in a patient suffering under amaurosis of one eye, the pupil of the affected eye is often found to vary in size, in accordance with that of the other eye; but this effect is due to the action of light on the retina of the sound eye, which produces a motor change in the third pair on both sides. Further, as already shown (§ 512), the *impression* only of light upon the retina may give rise to contraction of the pupil, by reflex action, when the optic nerve is itself sound; whilst no *sensations* are received through the eye, in consequence of disease in the sensorial portion of the nervous centres. Although the contraction of the pupil is effected by the influence of motor fibres, which proceed to the sphincter of the Iris from the third pair of nerves, *through* the Ophthalmic ganglion, its dilatation (as we shall hereafter see) depends upon the influence it derives from the Sympathetic system, of which that ganglion forms part. —Besides the contraction of the pupil, another action of a 'reflex' character is produced through the Optic nerve, namely, the contraction of the Orbicularis muscle under the influence of strong light, or when a foreign body is suddenly brought near the eye. But this cannot be excited without a consciousness of the visual impression; in fact, it is a movement of a 'consensual' kind, produced by the painful sensation of light, which gives rise to the condition well characterised by the term *photophobia*. The involuntary character of it must be evident to every one who has been engaged in the treatment of diseases of the eyes; and the effect of it is aided by a similarly-involuntary movement of the eyeball itself, which is rotated upwards and inwards, to a greater extent than the Will appears able to effect.—Another reflex movement excited through the visual sense, is that of Sneezing, which is induced in many individuals by the sudden exposure of the eyes to a strong light. Of the purely automatic character of this movement there can be no question, since it cannot be imitated voluntarily; and that it is not excito-motor, is proved by the fact that it is not excited unless the light be *seen*.*

523. There is a further peculiarity, of a very marked kind, attending the course of the Optic nerves; this is the crossing or 'decussation' which they undergo, more or less completely, whilst passing between their ganglia and the eyes. In some of the lower animals in which the two eyes (from their lateral position) have entirely different spheres of vision, the decussation is complete; the whole of the fibres from the right optic ganglion passing into the left eye, and *vice versâ*. This is the case, for example, with most of the Osseous Fishes (as the cod, halibut, &c.), and

* A patient was for some time in the London Hospital, in whom there was such an undue impressionality of the retina, that she could not remain in even a moderate light without a continual repetition of the act of Sneezing.

also, in great part at least, with Birds.* In the Human subject, however, and in animals which, like him, have the axes of both eyes directed to the same object, the decussation seems less complete; but there is a very remarkable arrangement of the fibres, which seems destined to bring the two eyes into peculiarly consentaneous action. The *posterior* border of the Optic Chiasma is formed exclusively of *commissural* fibres, which pass from one *optic ganglion* to the other, without entering the real optic nerve. Again, the *anterior* border of the Chiasma is composed of fibres, which seem, in like manner, to act as a commissure between the two *retinæ*; passing from one to the other, without any connection with the optic ganglia. The tract which lies between the two borders, and occupies the *middle* of the Chiasma, is the true Optic Nerve; and in this it would appear that a portion of the fibres decussates, whilst another portion passes directly from each Optic ganglion into the corresponding eye. The fibres which proceed from the ganglia to the retinæ, and constitute the proper Optic Nerves, may be distinguished into an internal and an external tract. Of these the *external*, on each side, passes directly onwards to the eye of *that* side; whilst the *internal* crosses over to the eye of the *opposite* side. The distribution of these two sets of fibres in the retina of each eye respectively, is such that, according to Mr. Mayo, the fibres from either optic ganglion will be distributed to *its own side* of *both* eyes;† the right optic ganglion being thus exclusively connected with the outer part of the retina of the right eye, and with the inner part of the retina of the left; whilst the left optic ganglion is connected exclusively with the outer side of the left retina, and with the inner side of the right. Now as either side of the eye receives the images of objects which are on the other side of its axis, it follows, if this account of the distribution of the nerves be correct, that in Man, as in the lower animals, each ganglion receives the impressions of objects situated on the *opposite* side of the body. The purpose of this decussation may be, to bring the visual impressions, which are so important in directing the movements of the body, into proper harmony with the motor apparatus; so that the decussation of the motor fibres in the pyramids being accompanied by a decussation of the optic nerves, the same effect is produced as if neither decussated,—which last is the case with Invertebrated animals in general.

524. The functions of the *Auditory* nerve, or *Portio Mollis* of the 7th, are easily determined, by anatomical examination of its distribution, and by observation of pathological phenomena, to be analogous to those of the two preceding. Atrophy or lesion of the trunk destroys the sense of Hearing; whilst irritation of it produces auditory sensations, but does not occasion pain. From experiments made upon the nerve before it leaves the cranial cavity, it appears satisfactorily ascertained, that this nerve is not endowed either with common sensibility, or with the power

* See Solly on "The Human Brain," 2nd edit., p. 288.

† This arrangement was first hypothetically suggested by Dr. Wollaston ("Philos. Trans.," 1824), as facilitating the explanation of some of the phenomena of vision, and more particularly single vision with two eyes. We shall hereafter see, however, that the singleness of the impression resulting from the formation of two pictures upon our retinæ, is not attributable to any such anatomical arrangement, their combination being a mental process, and the formation of two *dissimilar* pictures being requisite to enable us to exercise one of the highest attributes of the visual sense, the perception of *projection*. (See CHAP. XV. Sect. 5.)

of directly stimulating muscular movement. Nor can any obvious reflex actions be executed by irritation of this nerve; but it seems nevertheless by no means improbable, that the muscles which regulate the tension of the Tympanum, are called into action by impressions made upon it and reflected through the auditory ganglion, in the same manner as the diameter of the pupil is regulated through the optic nerve. In the involuntary start, however, which is occasioned by a loud and sudden sound, we have an example of a *consensual* movement excited through the Auditory nerve, which is evidently analogous to the closure of the eyes to a strong light. In certain morbidly-impressible states of the nervous system, as will be presently shown (§ 538), the effect of sounds on the motor apparatus is far more remarkable.—It has been attempted by Flourens to show, that the division of the Auditory nerve, which proceeds to the Semicircular canals, has functions altogether different from that portion which supplies the Vestibule and Cochlea. This inference, however, is grounded only upon the movements exhibited by animals in which these nerves are irritated; which movements are capable of a different explanation (§ 531).

525. The nerves which minister to the sense of *Taste*, are destitute of the peculiarities which distinguish the preceding, being no other than certain branches of ordinary afferent nerves,—the Fifth Pair and Glosso-pharyngeal (§ 495)—the peculiar endowments of which seem to depend rather upon the structure and actions of the papillæ at their peripheral extremities, than upon anything special in their own character. As in the case of the ordinary nerves of 'common' sensation, mechanical irritation applied to them calls-forth indications of pain.—From the observations and experiments of M. Cl. Bernard,* it appears that the Facial nerve (portio dura of the 7th) supplies some condition requisite for the sense of Taste, through the branch known as the Chorda Tympani, which is the motor nerve of the Lingualis muscle. When paralysis of the Facial exists in Man, the sense of taste is very much impaired on the corresponding side of the tongue, provided that the cause of the paralysis be seated above the origin of the Chorda Tympani from its trunk. Similar results have been obtained from experiments upon other animals. The nature of the influence afforded by this nerve is entirely unknown; and it is the more obscure, as the Chorda Tympani contains no sensory filaments.

526. *Nerves of Common Sensation.*—To the sense of *Touch*, all the afferent nerves of the body (save the nerves of special sense) appear to minister; in virtue—according to the doctrine already propounded (§ [illegible])—of the direct connection of certain of their fibrils with the *Sensorium commune*. But the degree in which they are capable of producing Sensations, does not bear any constant relation to their power of exciting reflex actions. Thus, the Glosso-pharyngeal is not nearly so *sensitive* as the Fifth pair; though more powerful as an *excitor* nerve. The Par Vagum appears to have even less power of arousing sensory changes, although it is the most important of all the excitors to reflex action. So again, the afferent nerves of the inferior extremities, in Man, are less concerned in ministering to sensations, than are those of the superior; and yet they appear to be much more efficient as excitors to muscular

* "Archives Générales de Medecine," 1844

movement.—These differences may be accounted-for, by supposing that the proportion which the fibres, having their centre in the ganglionic matter of the Spinal Cord, bears to that of the fibres which pass-on to the Sensorium, is not constant, but is liable to variation in different nerves; the former predominating in the Par Vagum and the Glosso-pharyngeal, whilst the latter are more numerous in the Fifth Pair, and in most of the Spinal nerves.

527. *Motor Nerves.*—No motor nerves issue from the Sensory Ganglia with the same directness that afferent nerves proceed towards them; but the reflex actions of these centres find a ready channel in the motor nerves of the Cranio-Spinal axis generally. For, as we have seen (§ 490), the motor tract of the Crura Cerebri, which is in connection with the motor Encephalic nerves, and also (through the vesicular substance of the Spinal Cord) with the anterior roots of the Spinal nerves, passes-up into the Corpora Striata and Corpora Quadrigemina. Although the direct connection of the other ganglia of Special Sense with the Motor columns, is at present a matter of presumption only, yet this presumption is strongly supported by the analogy of the Optic ganglia; the distinctness of this connection in *their* case being easily accounted-for, when it is remembered in how great a degree the general movements of the body are guided by the visual sense.

528. *Functions of the Sensory Ganglia.*—We have now to consider what deductions may be drawn with regard to the functions of the Sensory Ganglia in Man, from the facts supplied by Comparative Anatomy, by Experimental inquiry, and by Pathological phenomena. The determination of these functions may seem to be the more difficult, as it is impossible to make any satisfactory experiments upon the ganglionic centres in question, by isolating them completely from the Cerebral Hemispheres above, and from the Medulla Oblongata and Spinal Cord below. But the evidence derived from Comparative Anatomy appears to be in this case particularly clear; and, rightly considered, affords us nearly all the information we require. In the series of "experiments prepared for us by nature," which is presented to us in the descending scale of Animal life, we witness the effects of the gradual change in the relative development of the Sensory ganglia and Cerebral Hemispheres, which are presented to us in descending through in the Vertebrated scale; and the results of the entire withdrawal of the latter, and of the sole operation of the former, which are exhibited in the higher Invertebrata (See §§ 458, 461, and PRINC. OF COMP. PHYS., CHAP. XIII.).*—Thus we are led by the very cogent evidence which Comparative Anatomy supplies, to regard this series of Ganglionic centres as constituting the real *Sensorium;* each ganglion having the power of rendering the Mind conscious of the impressions derived from

* It is worthy of special notice, that the development of the Cephalic ganglia in the Invertebrata always bears an exact proportion to the development of the *eyes*, the other organs of special sense being comparatively undeveloped, whilst these, in all the higher classes at least, are instruments of great perfection, and are evidently connected most intimately with the direction of the movements of the animals. Of this fact we have a remarkable illustration in the history of the metamorphosis of Insects, the eyes being almost rudimentary, and the Cephalic ganglia comparatively small, in most Larvæ, whilst both these organs attain a high development in the Imago, to whose actions the faculty of sight is essential.

the organ with which it is connected. If this position be denied, we must either refuse the attribute of consciousness to such animals as possess no other Encephalic centres than these; or we must believe that the *addition* of the Cerebral hemispheres, in the Vertebrated series, alters the endowments of the Sensory ganglia,—an idea which is contrary to all analogy.

529. So far as the results of Experiments can be relied-on, they afford a corroboration of this view. The degree in which animals high in the scale of organization can perform the functions of life, without any other centre of action than the Ganglia of Special sense, the Medulla Oblongata, and the Cerebellum, appears extraordinary to those who are accustomed to regard the Cerebral Hemispheres as the centre of all energy. From the experiments of Flourens,* Hertwig,† Magendie,‡ Longet,§ and others, it appears that not only Reptiles, but Birds and Mammals, may survive for many weeks or even months (if their physical wants be duly supplied) after the removal of the entire Cerebrum. It is difficult to substantiate the existence in them of actual *sensation;* but some of their movements appear to be of a higher kind than those resulting from mere excito-motor action. One of the most remarkable phenomena exhibited by such a being, is the power of maintaining its equilibrium, which could scarcely exist without consciousness. If it be laid upon the back, it rises again; if pushed, it walks. If a Bird thus mutilated be thrown into the air, it flies; if a Frog be touched, it leaps. It swallows food and liquid, when they are placed in its mouth; and the digestive operations, the acts of excretion, &c., take place as usual. In the case of a Pigeon experimented-on by Malacorps, which is recorded by Magendie, there appears sufficient proof of the persistence of a certain amount of sensation. Although the animal was not affected by a strong light suddenly made to fall upon its eyes, it was accustomed, when confined in a darkened or partially-illuminated room, to seek-out the light parts and *it avoided objects that lay in its way.* In the same manner, it did not seem to be affected by sudden noises; but at night, when it slept with its eyes closed and its head under its wing, it would raise its head in a remarkable manner, and open its eyes, on the slightest noise; speedily relapsing into a state of complete unconsciousness. Its principal occupation was to prune its feathers and scratch itself. And Longet mentions that a Pigeon from which he had removed the entire Cerebrum, gave many indications of consciousness of light; for not only did the pupil contract, but the lids closed, when a strong light was suddenly made to fall upon the eye, the animal having been previously kept in darkness; and *when a lighted candle was made to move in a circle before it, the animal executed a corresponding movement with its head.*||—The condition of such

* "Recherches Expérimentales sur les propriétés et les fonctions du Système Nerveux," 2nd edit., 1845.

† "Exper. de effect. læsion. in partibus Encephali," Berol., 1826.

‡ "Leçons sur les Fonctions du Système Nerveux," Paris, 1839.

§ "Traité de Physiologie," tom. ii. partie 2.

|| It must not be forgotten that, in such experiments, the severity of the operation will of itself occasion a suspension or disturbance of the functions of parts that remain; so that the *loss* of a power must not be at once inferred from the absence of its manifestations; but the *persistence* of a power, after the removal of a particular organ, is a clear proof that it cannot be the peculiar attribute of that organ.

being seems to resemble that of a Man, who is in a slumber sufficiently deep to lose all distinct *perception* of external objects, but who is yet conscious of *sensations*, as appears from the movements occasioned by light or by sounds, or from those which he executes to withdraw the limb from an uneasy position.

530. The results of other experiments made upon the Sensory ganglia themselves, and upon the organs from which they derive their impressions, confirm this view; by showing that the ordinary movements are variously perturbed, and that in some instances a new set of automatic movements is induced, when the normal relations between the sensory and motor apparatus are disarranged. Of the functions of the ganglia of special sense, those of the *Corpora Quadrigemina* are the chief which have been examined experimentally. The researches of Flourens and Hertwig have shown, that the connection of these bodies with the visual function, which might be inferred from their anatomical relations, is thus substantiated. The partial loss of the ganglion on one side produces partial loss of power and temporary blindness on the opposite side of the body, without necessarily destroying the mobility of the pupil; but the removal of a larger portion, or complete extirpation of it, occasions permanent blindness and immobility of the pupil, with temporary muscular weakness on the opposite side. This temporary disorder of the muscular system sometimes manifests itself in a tendency to move on the axis, as if the animal were giddy. No disturbance of consciousness appears to be produced; and Hertwig states that he never witnessed the convulsions, which Flourens mentions as a consequence of the operation, and which were probably occasioned by his incision having been carried too deeply. As Longet has justly remarked, it is difficult, if not impossible, to remove one or both of these ganglionic masses, without doing such an injury to the Crura Cerebri on which they repose, as shall in great degree account for such disturbed movements (§ 534). Irritation of *one* of the Tubercula Quadrigemina has been observed, both by Flourens and Longet, to produce contraction of the pupils of *both* eyes.—These results of experiment are partly confirmed by Pathological phenomena in Man; for there are many instances on record, in which blindness has been one of the consequences of diseased alterations in one or both tubercles; and in some of the cases in which the lesion extended to parts seated beneath the tubercles, disturbed movements were observed.—The subservience of these bodies to the exercise of the visual sense, appears, on the whole, to be the point best established in regard to their functions, and considering the degree in which this sense is concerned in the regulation of the general movements of the body, it is not surprising that lesions of its centre should occasion a perversion of these movements. This appears the more probable from the fact, that, in animals whose Sensory ganglia bear so large a proportion to the whole Encephalon, that we must look upon them as the principal centres of motor activity, instead of being chiefly concerned (as in Man) in the mere guidance of movements whose origin is Cerebral, lesions of the organ of sense, from which the impressions that excite the sensori-motor impulses are derived, produce a corresponding disturbance. Thus Flourens found that a vertiginous movement may be induced in Pigeons by simply blinding one eye; and Longet produced the same effect by evacuating the humours of the eye.

531. It is probably on the same principle, that we are to account for the remarkable results obtained by Flourens (Op. cit.) from section of the portion of the Auditory nerve proceeding to the Semi-circular canals. Section of the horizontal semi-circular canal in Pigeons, on both sides, induces a rapid jerking horizontal movement of the head, from side to side; and a tendency to turn to one side, which manifests itself whenever the animal attempts to walk forwards. Section of a vertical canal, whether the superior or inferior, of both sides, is followed by a violent vertical movement of the head. And section of the horizontal and vertical canals, at the same time, causes horizontal and vertical movements. Section of either canal on one side only, is followed by the same effects as when the canal is divided on both sides; but this is inferior in intensity. The movements continue to be performed during several months. In Rabbits, section of the horizontal canal is followed by the same movements as are exhibited by Pigeons; and they are even more constant, though less violent. Section of the anterior vertical canal causes the animal to make continued forward 'somersets,' whilst section of the posterior vertical canal occasions continued backward 'somersets.' These movements cease when the animal is in repose, and they recommence when it begins to move, increasing in violence as its motion is more rapid.—These curious results are supposed by M. Flourens to indicate, that the nerve supplying the semi-circular canals does not minister to the sense of hearing, but to the direction of the movements of the animal; but they are fully explained upon the supposition, that the normal function of the semi-circular canals is to indicate to the animal the *direction* of sounds, and that its movements are partly determined by these; so that a destruction of one or other of them will produce an irregularity of movement (resulting, as it would seem, from a sort of giddiness on the part of the animal), just as when one of the eyes of a bird is covered or destroyed, as in the experiments previously cited.

532. The numerous experiments which have been made, for the purpose of determining the functions of the Thalami Optici and Corpora Striata, have not yielded any very satisfactory results; and this on account of the impossibility of completely isolating them, in such a manner as to limit the operation (whether this be section, removal, or irritation) to them alone. Thus it is impossible to remove them, either separately or conjointly, without first removing the Cerebral Hemispheres; and the Thalami cannot be entirely removed, without dividing the stratum of fibres which traverse their deeper portion in their passage to the Corpora Striata.—The Thalami Optici have not that relation to the visual sense which their designation would imply; for (according to the affirmations of Longet) they may be completely destroyed in Mammals and Birds without destruction of sight or loss of the activity of the pupil. And irritation of one or both of them produces no contraction of the pupil. It seems probable, therefore, that the loss of sight with dilatation and immobility of the pupil, which is frequently observed in cases of apoplectic effusion into the substance of the Thalami, is really due to the compression of the Optic nerves which lie beneath them. These bodies appear, however, to possess a very decided influence on the power of voluntary movement; for although an animal maintains its balance, and can be made to move onwards, after the removal of the Cerebral Hemispheres

and even after the removal of the Corpora Striata, yet if either of the Thalami Optici be removed, the sensibility and power of voluntary movement are destroyed on the *opposite* side of the body, and the animal consequently falls over to that side (Longet). If, instead of the entire removal of one of the Thalami, an incision be made in it without the previous removal of the Cerebrum, the animal keeps turning to one side in a circular manner (evolution du manège): according to Longet and Lafargue, this movement is directed in the rabbit towards the opposite side; whilst Flourens states that in the frog its direction is towards the injured side; and according to Schiff* the destruction of the three anterior fourths of this organ in the rabbit determines this movement towards the injured side, whilst that of the posterior fourth determines the movement towards the opposite side. No mechanical irritation of the Thalami produces either signs of pain or muscular movement, and this fact might at first appear to negative the doctrine that these organs are the ganglia of common sensation. But it must be borne in mind that the production of pain by mechanical injuries, is by no means an universal phenomenon in the case of the nerve-*trunks* which minister to sensation, —the olfactive, optic, and auditory nerves being exempted; and it need occasion still less surprise, therefore, that a nervous *centre* should be destitute of this kind of impressibility.

533. The effects of lesions of the Corpora Striata are less distinctly marked. It was affirmed by Magendie, that there exists in them a motor power which excites *backward* movement, and that a corresponding power of exciting *forward* movement exists in the Cerebellum; that these two powers ordinarily balance one another; but that, if either organ be removed, the power of the other will occasion a continual automatic movement, the removal of the Corpora Striata causing an irresistible tendency to forward progression, whilst the division of the peduncles of the Cerebellum (according to him) occasions the reverse movement. These assertions, however, have not been confirmed by other experimenters. According to Longet (Op. cit.), Schiff,† and Lafargue,‡ the results of removal of the Corpora Striata with the anterior part of the Cerebral hemispheres, are for the most part negative; for the animal usually remains in a state of profound stupor, although still retaining the erect position; and it is only when irritated by pinching or pricking, that it will execute any rapid movements. No mechanical irritation of the Corpora Striata produces either signs of pain or muscular movement.

534. When the fibrous tracts which connect these ganglionic masses with the Medulla Oblongata, and which are commonly (but erroneously) designated as the *Crura Cerebri*, are completely divided, the result, as might be anticipated, is the annihilation of sensibility and of the power of voluntary movement in the body generally.§ When, however, the Crura

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§ It is considered by Longet that these functions are not *completely* destroyed, because the animals on whom this operation has been performed still retain some power of movement, and respond by cries to impressions that ordinarily produce pain. There is no proof, however, that such actions are other than 'excito-motor;' they certainly cannot in themselves be admitted as proving the persistence of consciousness in the lower segment of the Cerebro-Spinal axis.

Cerebri of a rabbit are not completely divided, but one of them is partially cut-through, a little in front of the Pons Varolii, the animal is seen by Longet and Schiff to exhibit a constant tendency to turn towards the side opposite to that of the lesion, so that it performs the circular *evolutions du manége*, the diameter of its circle of movement being smaller, in proportion as the incision approaches the edge of the Pons. But if one of the Crura be completely divided, the animal then falls-over on the opposite side; the limbs of that side being paralysed to the influence of the Encephalic centres, though they may be still caused to exhibit reflex motions. Hence it appears that the circular movements which are performed after incomplete lesions of the Crus Cerebri and Thalamus Opticus of either side, are due to the weakening of the sensori-motor apparatus of the opposite side, whereby the balance of the muscular actions of the two sides is destroyed. Nearly the same results have been obtained on this point by Longet, Lafargue, and Schiff.

535. Considerable importance is attached by some Physiologists to the part of the Encephalon known as the *Tuber Annulare*, to which the name of *Mesocephale* has also been given. This is not altogether synonymous with the *Pons Varolii*, as some Anatomists have represented it; for, while the latter consists of transverse fibres, which form the commissure between the hemispheres of the Cerebellum, surrounding and passing between the longitudinal fibres of the Sensory and Motor tracts which constitute the Crura Cerebri, the Tuber Annulare (which exists in animals whose Cerebellum has no hemispheres) is a projection from the surface of the proper Medulla Oblongata, containing a considerable nucleus of vesicular matter. The experiments of Longet have led him to the conclusion, that this ganglionic mass is an independent centre of sensation and of motor power; but they do not afford any clear information as to its special attributes. He states, however, that convulsive movements are excited by irritating it, and especially by the transmission of an electric current through its substance. These movements, however, according to the testimony of Dr. Todd, appear to be of a different character from those which are excited by the application of the same stimulus to the Spinal Cord and Medulla Oblongata; for he states that whilst the convulsions excited by the transmission of the current of the magneto-electric machine through the parts just named, are *tetanic*, the muscles being thrown into a state of *fixed* contraction,—those which ensue when the current is transmitted through the region of the Mesocephale and Corpora Quadrigemina, are *epileptic*, being combined movements of *alternate* contraction and relaxation, flexion and extension, affecting the muscles of all the limbs, of the trunk, and of the eyes, which roll-about just as in epilepsy.*

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536. The evidence afforded by Pathology, regarding the functions of these Ganglionic masses, is far from being self-consistent; and this arises, it may be surmised, from the circumstance that the effects of morbid changes (particularly of sanguineous effusions) in any part of the Encephalon, extend themselves to other parts than those in which the obvious lesions are found; as is abundantly proved by the great variety of pheno-

* Lumleian Lectures 'On the Pathology and Treatment of Convulsive Diseases,' in "Medical Gazette," May 11, 1849.

mena which present themselves as the results of lesions apparently similar, and by the similarity of the phenomena that are frequently consequent upon lesions of very different parts. So far as is yet known, extensive disease of either the Thalamus Opticus or the Corpus Striatum of one side produces hemiplegia, or paralysis both of sensation and motion, on the opposite side. The same result very commonly follows an apoplectic effusion into the substance of either, and although it has been maintained that when the lesion is limited to the Corpus Striatum, the posterior member is peculiarly or alone affected, and that lesion of the Thalamus Opticus alone has a special tendency to occasion paralysis of the anterior member, yet the careful analysis which has been made by Andral* into the pathological phenomena afforded by seventy-five cases of paralysis in which the apoplectic effusion was limited to one or other of these bodies, does not afford the least countenance to any such doctrine. And it is affirmed by Longet, that injury or removal of the Corpus Striatum of one side did not, in his experiments, affect the posterior more than the anterior limb; nor could he detect any difference in the condition of these limbs after the removal of the Thalamus.

537. In employing the information derived from the foregoing sources, as a guide in the enquiry into the part performed by the Sensory Ganglia in the ordinary operations of the Cerebro-Spinal system, we have to distinguish, as in the case of the Spinal Cord, between their operation as independent centres, and their action in subservience to the Cerebrum, which is superposed upon them.—We have seen reason to conclude that, in their former capacity, they are to be regarded as the true seat of *Sensation* (*i. e.* the material instruments through which the consciousness becomes affected by external impressions), and as the instrument, in virtue of their own 'reflex' power, of that class of Instinctive or Automatic movements, which require to be prompted and guided by sensations, and which cannot, therefore, be referred to the excito-motor group. But although it is sufficiently obvious that such movements constitute the highest manifestations of Animal life in the Invertebrata generally, and that they are but little modified by any higher principle of action even in the lower Vertebrata, yet it is no less obvious that in adult Man, in whom the Intelligence and Will are fully developed, we have comparatively little evidence of this independent reflex action of the Sensory Ganglia:—all those automatic actions which are *immediately* necessary for the maintenance of his Organic life, being provided for by the excito-motor portion of the apparatus, so that although sensation ordinarily accompanies most of them, it is not essential to them; whilst those which are necessary to provide more *remotely* for its requirements, are for the most part committed to the guidance of his Reason. For the impressions which have been brought by the afferent nerves to his Sensorium, and which have there produced sensations, do not in general react at once upon the motor apparatus (as they do in those animals in which the Sensory Ganglia are the *highest* of the nervous centres), but usually transmit their influence upwards to the Cerebrum, through whose instrumentality they give rise to ideas and reasoning processes, which operate upon the motor apparatus either emotionally or volitionally. And it is for the most part only when this

* "Clinique Médicale," tom. ii. p. 664, et seq.

upward transmission is checked, either by the non-development or the functional inactivity of the Cerebrum, or by its complete occupation in some other train of action,—or, on the other hand, when the reflex action of the Sensory ganglia is called into play with unusual potency,—that we have any manifestations of the *sensori-motor* or *consensual* mode of operation in Man, that are at all comparable in variety or importance to those instinctive acts which are so remarkable in the lower animals (§ [illegible]).

538. Still, sufficient evidence of the existence of this class of reflex movements may be drawn from observation of the actions of Man in his ordinary condition; examples of it being furnished (as we have seen) by the closure of the eyes to a dazzling light, the start caused by a loud and unexpected sound, and the sneezing excited by sensory impressions on the Schneiderian membrane or on the Retina. To these may be added the vomiting produced by various sensory impressions, as the sight of a loathsome object, a disagreeable smell, a nauseous taste, or that peculiar feeling of want of support which gives rise to 'sea sickness,' especially when combined with the sight of continually shifting lines and surfaces, which itself in many individuals disposes to the same state; the involuntary laughter which is excited by tickling, and also that which sometimes bursts forth at the provocation of some sight or sound, to which no ludicrous idea or emotion can be attached; the yawning which is excited by an internal sensation of uneasiness (usually arising from deficient respiration), or by the sight or sound of the act as performed by another; and those involuntary movements of the body and limbs excited by uneasy sensations (probably muscular), which are commonly designated as 'the fidgets.' When the reflex activity of the Sensory ganglia is more strongly excited, in consequence either of an unusual potency of the sensory impressions, or of an unusual excitability of this part of the nervous centres, a much greater variety of sensori-motor actions is witnessed. The powerful involuntary contraction of the orbicularis and of the muscles which roll the eyeball upwards and inwards, in cases of excessive irritability of the retina (§ 522), is one of the best examples of this kind; but another very curious illustration is afforded by the involuntary abridgment of the excito-motor actions of respiration, when the performance of these is attended with pain,—the dependence of this abridgment upon the direct stimulus of sensation, rather than upon voluntary restraint, being obvious from the fact that it often presents itself on *one* side only, a limitation which the Will cannot imitate. Again, there are certain Convulsive disorders (Sect. 8) which appear to depend upon an undue excitability of these centres, the paroxysms being excited by impressions which act through the organs of sense, and are not thus operative unless the patient be conscious of them; thus in Hydrophobia, we observe the immediate influence of the sight, sound, or contact of liquids, or of the slightest currents of air, in exciting muscular contractions; and in many Hysteric subjects, the sight of a paroxysm in another individual is the most certain means of its induction in themselves. A remarkable case of this general exaltation of purely sensorial excitability has been recorded by Dr. Cowan; who gives the following account of its phenomena, which can scarcely be referred to any other than this category. "The shadow of a bird crossing the window, though the blind and bed-curtains are closed, the displacement of the smallest portion of the

wick of a candle, the slightest changes in the firelight, induce a sudden jerking of the spinal muscles, extending to the arms and legs when violent, and this without the slightest mental emotion of any kind beyond a consciousness of the movement. At times the vocal organs are implicated, and a slight cry, quite involuntary, takes place. At these periods she is unusually susceptible of all noises, especially the least expected and least familiar. Movements in the next house inaudible to others, the slightest rattle in the lock of a door, tearing a morsel of paper, and a thousand little sources of sound not to be catalogued, induce results similar to those of visual impressions." *

539. It is, however, when the Cerebrum is not in a state which renders it capable of receiving and acting-upon Sensorial impressions, that we find the independent reflex activity of the Sensory ganglia most strikingly displayed. Thus in the Infant, for some time after its birth, it is obvious to an attentive observer, that a large part of its movements are directly prompted by sensations to which it can as yet attach no distinct ideas, and that they do not proceed from that *purposive* impulse which is essential to render them voluntary. This is well seen in the efforts which it makes to find the nipple with its lips; being probably guided thereto at first by the smell, but afterwards by the sight also; when the nipple has been found, the act of suction is purely excito-motor, as already explained. So in the Idiot, whose brain has never attained its normal development, the influence of sensations in directly producing respondent movements is obvious to all who examine his actions with discrimination; and a remarkable case will be cited hereafter (Sect. 8), in which an entire, though temporary suspension of Cerebral power, reducing the subject of it to the condition of one of the lowest Vertebrata, gave a very satisfactory proof of the independent activity of this division of the Encephalic centres.

540 But we do not require to go so far in search of characteristic examples of this kind of reflex action; since they are afforded by the performance of *habitual* movements, which are clearly under Sensorial guidance, when the Cerebrum is occupied in some train of action altogether disconnected with them. An individual who is subject to 'absence of mind,' may fall into a reverie whilst walking the streets, his attention may be entirely absorbed in his train of thought, and he may be utterly unconscious of any interruption in its continuity; and yet, during the whole of that time, his limbs shall have been in motion, carrying him along the accustomed path, whilst his vision shall have given the direction to these movements, which is requisite to guide him along a particular line, or to move him out of it for the avoidance of obstacles. As already pointed-out (§ 514), there seems strong reason for regarding the ambulatory movements of the limbs as in themselves excito-motor; but the *guidance* of these movements by the visual sense, indicates the participation of the Sensorium in this remarkable performance.—It has been maintained by some Metaphysicians and Physiologists, that these 'secondarily automatic' actions always continue to be voluntary, because their performance is originally due to a succession of volitional acts, and because, in any particular case, it is the Will which first excites them, whilst an exertion of the Will serves to check them at any time. But

* "Lancet," Oct. 4, 1845.

this doctrine involves the notion, that the Will is in a state of pendulum-like oscillation between the train of thought and the train of movement; whereas nothing is more certain to the individual who is the subject of both, than that the former may be as uninterrupted as if his body were perfectly at rest, and his reverie were taking place in the quietude of his own study. And as it commonly happens, that the direction taken is that in which the individual is most in the habit of walking, it will not unfrequently occur that if he had previously intended to pursue some other, he finds himself, when his reverie is at an end, in a locality which may be very remote from that towards which his walk was originally directed; which would not be the case, if his movements had been still under the purposive direction of the will. And although it is perfectly true that these movements can be at any time checked by an effort of the will, yet this does not really indicate that the will has been previously engaged in sustaining them; since, for the will to act upon them at all, the attention must be recalled to them, and the Cerebrum must be liberated from its previous self-occupation. And the gradual conversion of a volitional into an automatic train of movements, so that at last this train, once started, shall continue to run-down of itself, will be found to be less improbable than it would at first appear, when it comes to be understood that the mechanism of both sets of actions is essentially the same, and that they merely differ as regards the nature of the stimulus which originally excites them (§ 549). That the same automatic movements are not excited by the same sensations, when the Cerebrum is in its ordinary state of functional connection with the Sensorium, is a fact entirely in harmony with the principle already laid down (§§ 468-470). The complete occupation of the mind in other ways, as in close conversation or argument, or even (it may be) in the voluntary direction of some other train of muscular movements, is no less favourable than the state of reverie to that independent action of the Automatic centres which has been now described.

541. In the state of entire functional activity of the nervous centres of Man, however, there can be no doubt that the operation of the Sensory Ganglia is entirely subordinated to that of the Cerebrum; and that it furnishes an essential means of connection between the actions of the Cerebrum on the one hand, and those of the organs of Sense and Motion on the other, by the combination of which the Mind is brought into relation with the external world. For, in the first place, it may be affirmed with certainty, that no mental action can be originally excited save by the stimulus of Sensations; and it is the office of the Sensory ganglia to form these out of the impressions brought to them from the organs of sense, and to transmit such sensorial changes to the Cerebrum. But they have a no less important participation in the downward action of the Cerebrum upon the motor apparatus; for no voluntary action can be performed without the assistance of a *guiding sensation*, as was first prominently stated by Sir C. Bell.* In the majority of cases, the guiding or controlling sensation is derived from the muscles themselves, of whose condition we are rendered cognizant by the sensory nerves with which they are furnished; but there are

* See his chapter 'On the Nervous Circle which connects the voluntary muscles with the Brain,' in his work "On the Nervous System of the Human Body."

certain cases in which it is ordinarily derived from one of the special senses, and in which the 'muscular sense' (§ 556) can only imperfectly supply the deficiency of such guidance; whilst, again, if the 'muscular sense' be deficient, one of the special senses may supply the requisite information. The proof of this necessity is furnished by the *entire impossibility of making or sustaining voluntary efforts, without a guiding sensation of some kind.* Thus, in complete anæsthesia of the lower extremities, without loss of muscular power, the patient is as completely unable to walk, as if the motor nerves had also been paralyzed, unless the deficient sensorial guidance be replaced by some other; and in similar affections of the upper extremities, there is a like inability to raise the limb or to sustain a weight. But in such cases, the deficiency of the 'muscular sense' may be made good by the visual; thus, the patient who cannot feel either the contact of his foot with the ground, or the muscular effort he is making, can manage to stand and walk by *looking* at his limbs; and the woman who cannot feel the pressure of her child upon her arms, can yet sustain it so long as she keeps her eyes fixed upon it, but no longer,—the muscles ceasing to contract, and the limb dropping powerless, the moment that the eyes are withdrawn from it. Thus it is, too, that when we are about to make a muscular effort, the amount of force which we put-forth is governed by the mental conception of that which will be required, as indicated by the experience of former sensations; just as the contractions of the muscles of vocalization are regulated by the conception of the sound to be produced. Hence if the weight be unknown to us, and it prove either much heavier or much lighter than was expected, we find that we have put-forth too little or too great a muscular effort.

542. There are two groups of muscular actions, however, which, although no less voluntary in their character than the foregoing, are yet habitually guided by other sensations than those derived from the muscles themselves. These are, the movements of the *Eyeball*, and those of the *Vocal apparatus.*—The former are directed by the visual sense,* by which the action of the muscles is guided and controlled, in the same manner as that of other muscles is directed by their own 'muscular sense'; and hence it happens that, when we close our eyes, we cannot move them in any required direction, without an effort that strongly calls-forth the muscular sense, by which the action is then guided. In persons who have become blind after having once enjoyed sight, an association is formed by habit between the muscular sense and the contractile action, that enables the former to serve as the guide after the loss of the visual sense; but in those who are born *perfectly* blind, or who have become so in early infancy, this association is never formed, and the eyes of such persons exhibit a continual indeterminate movement, and cannot by any amount of effort be steadily fixed in one spot, or be turned in any definite direction. A very small amount of the visual sense, however, such as serves merely to indicate the direction of light, is sufficient for the government of the movements of the eye-ball.—In the production of vocal sounds, again, that nice adjustment of the muscles of the Larynx, which is requisite to the giving forth of deter-

* See Dr. Alison's Memoir on the 'Anatomical and Physiological Inferences from the Study of the Nerves of the Orbit,' in "Trans. of Roy. Soc. of Edinb.," vol. xv.

minate tones, is ordinarily directed by the auditory sense; being learned in the first instance under the guidance of the sounds actually produced; but being subsequently effected voluntarily, in accordance with the mental conception (a sort of inward sensation) of the tone to be uttered, which conception cannot be formed, unless the sense of hearing has previously brought similar tones to the mind. Hence it is that persons who are born *deaf*, are also *dumb*. They may have no malformation of the organs of speech; but they are incapable of uttering distinct vocal sounds or musical tones, because they have not the guiding conception, or recalled sensation, of the nature of these. By long training, however, and by imitative efforts directed by muscular sensations in the larynx itself, some persons thus circumstanced have acquired the power of speech; but the want of a sufficiently definite control over the vocal muscles is always very evident in their use of the organs. It is very rarely that a person who has once enjoyed the sense of hearing afterwards becomes so *completely* deaf, as to lose all auditory control over his vocal organs. An example of this kind, however, has been communicated to the public by a well-known author, as having occurred to himself; and the record of his experiences* contains many points of much interest. The deafness was the result of an accident occurring in childhood, which left him for some time in a state of extreme debility; and when he made the attempt to speak, it was with considerable pain in the vocal organs. This pain probably resulted from the unaccustomed effort which it was necessary to make, when the usual guidance was wanting, being analogous to the uneasiness which we experience when we attempt to move our eyes with the lids closed. His voice at that time is described as being very similar to that of a person born deaf-and-dumb, but who has been taught to speak. With the uneasiness in the use of the vocal organs, was associated an extreme mental indisposition to their employment, and thus, for some years, the voice was very little exercised. Circumstances afterwards forced it, however, into constant employment; and great improvement subsequently took place in the power of vocalization, evidently by attention to the indications of the muscular sense. It is a curious circumstance further confirming this view, that the words which had been in use previously to the supervention of the deafness, were still pronounced (such of them, at least, as were kept in employment) as they had been in childhood, the muscular movements concerned in their articulation having still been guided by the original auditory conception, in spite of the knowledge derived from the information of others, that such pronunciation was erroneous. On the other hand, all the words subsequently learned were pronounced according to their spelling, the acquired association between the muscular sensations and the written signs being in this case the obvious guide.

543. It is through the 'muscular sense', in combination with the visual and tactile, that those movements are regulated, which are concerned alike in ordinary progression, and in the maintenance of the equilibrium of the body. That the visual sense has, in most persons, a large share in this regulation, is evident from the simple fact, that no

* See the "Lost Senses," by Dr Kitto, vol. i., chapters 2 and 3.

one who has not been accustomed to the deprivation of it, can continue to walk straight-forwards, when blind-folded, or in absolute darkness, towards any point in the direction of which he may have been at first guided. But the blind man, who has been accustomed to rely exclusively upon his muscular sense, has no difficulty in keeping to a straight path; and moves onwards with a confidence which is in remarkable contrast with the gait of a man who has been deprived of sight for the occasion only In fact, as Mr. Mayo has well remarked,* in our ordinary movements, "we lean upon our eyesight as upon crutches."—When our vision, however, instead of aiding and guiding us, brings to the mind sensations of an antagonistic character, our movements become uncertain, from the loss of that power of guidance and control over them, which the harmony of the two sensations usually gives. Thus a person unaccustomed to look down heights, *feels* insecure at the top of a tower or a precipice, although he *knows* that his body is properly supported; for the void which he sees below him contradicts (so to speak) the tactile sensations by which he is made conscious of the due equilibrium of his body. So, again, although any one can walk along a narrow plank, which forms part of the floor of a room, or which is elevated but a little above it, without the least difficulty, and even without any consciousness of effort, if that plank be laid across a chasm, the bottom of which is so far removed from the eye that the visual sense gives no assistance, even those who have braced their nerves against all emotional distraction, feel that an effort is requisite to maintain the equilibrium during their passage over it; that effort being aided by the withdrawal of the eyes from the abyss below, and the fixation of them on a point beyond, which at the same time helps to give steadiness to the movements, and distracts the mind from the sense of its danger. The degree in which the 'muscular sense' is alone sufficient for the guidance of such movements, when the mind has no consciousness of the danger, and when the visual sense neither affords aid nor contributes to distract the attention, is remarkably illustrated by the phenomena of Somnambulism; for the sleep-walker traverses, without the least hesitation, the narrow parapet of a house, and crosses narrow and insecure planks, clambers roofs, &c., under circumstances that clearly indicate the nature of the guidance by which he is directed (§ 693).—The dependence of our ordinary power of maintaining our equilibrium, upon the combination of the guiding sensations derived through the sight and the touch, is further well illustrated, as Mr. Mayo has pointed-out (loc. cit.), by what happens to a landsman on first going to sea. "It is long before the passenger acquires his 'sea legs.' At first, as the ship moves, he can hardly keep his feet, the shifting lines of the vessel and surface of the water unsettle his visual stability; the different inclinations of the planks he stands-on, his muscular sense. In a short time, he learns to disregard the shifting images and changing motions, or acquires facility in adapting himself (like one on horseback) to the different alterations in the line of direction in his frame." And when a person who has thus learned by habit to maintain his equilibrium on a shifting surface, first treads upon firm ground, he feels himself almost as much at fault

* "Outlines of Physiology," 3rd Edit., p. 355.

as he did when he first went to sea: and it is only after being some time on shore, that he is able to resume his original manner of walking. Indeed, most of those who spend the greater part of their time at sea, acquire a peculiar gait, which becomes so habitual to them, that they are never able to throw it off.

544. But further, there is very strong physiological evidence, that the Sensory Ganglia are not merely the instruments whereby our voluntary movements are directed and controlled, in virtue of the guiding sensations which they furnish, but that they are actually the immediate centres of the motor influence which excites muscular contractions in obedience to impulses transmitted downwards from the Cerebrum. It has usually been considered that the Cerebrum acts directly upon the muscles, in virtue of a direct continuity of nerve-fibres from the grey matter of its convolutions, *through* the Corpora Striata, the motor tract of the Medulla Oblongata, the anterior portion of the Spinal Cord, and the anterior roots of the nerves; and that in the performance of any voluntary movement, the Will determines the motor force to the muscle or set of muscles, by whose instrumentality it may be produced. To this doctrine, however, the anatomical facts already stated (§§ [illegible]) constitute a very serious objection; for the motor tract cannot be stated with certainty to have any higher origin than the Corpora Striata, and it is impossible to imagine that the fibres which converge towards the surface of these bodies from all parts of the Cerebrum, can be so closely compacted-together, as to be included in the motor columns of the Spinal Axis. The fact would rather seem to be, that these converging fibres bear the same kind of anatomical relation to the Corpora Striata and the other Sensorial centres of motor power, as do the fibres of the afferent nerves which proceed to them from the Retina, the Schneiderian membrane, and other peripheral expansions of nervous matter; and hence we might infer that the nerve-force generated in the convolutions, instead of acting *immediately* on the motor nerves, is first directed towards the Automatic centres, and excites the same kind of motor response in them, as would be given to an impression transmitted to them through a sensory nerve. We shall find that such a view of the structural arrangements of these parts is in remarkable accordance with their functional relations, as indicated by a careful analysis of the mechanism of what is commonly regarded as 'voluntary' movement. The Cerebrum, as will be shown hereafter (Sects. 5, 6), may thus call the motor apparatus into action, as the instrument either of *ideas or emotions*, or of *volitional determinations;* but we may limit our present examination to *voluntary* movements alone, these having been usually regarded as in such complete antagonism to those of the automatic group, that even separate sets of nerve-fibres have been thought requisite, to account for the transmission of these two distinct orders of motor impulses to the muscles.

545. Now in the first place, it may be asserted with some confidence, that no effort of the Will *can* exert that direct influence on the muscles, which our ordinary phraseology, and even the language of scientific reasoners, would seem to imply; but, on the other hand, that the Will is solely concerned in determining the *result*; the selection and combination of muscular movements required to bring about this result, *not* being

effected by the Will, but by some intermediate agency. If it were otherwise, we should be dependent upon anatomical knowledge for our power of performing the simplest movement of the body; whereas we find the fact to be, that the man who has not the least idea of the mechanism of muscular action, can acquire as complete a command over his movements, and can adapt them as perfectly to the desired end, as the most accomplished anatomist could do. Further, we cannot, by any exertion of the will, single-out a particular muscle, and throw it into contraction by itself, unless that muscle be one which is alone concerned in an action that we can voluntarily perform; and even then we single it out by *willing* the action. Thus we can put the *levator palpebræ* in action by itself; but this we do, not by any conscious determination of power to the muscle itself, but by *willing* to raise the eyelids; and it is only by our anatomical knowledge, that we know that but a single muscle is concerned in this movement. So far as our own consciousness can inform us, there is no difference between the mechanism of this action and that of the flexion of the knee- or elbow-joint; and yet in these latter movements, several muscles are concerned, not one of which can be singled-out by an effort of the will, and thrown into action separately from the rest.—The idea that the will is *directly* exerted upon the muscles called into action to produce a particular movement, may seem to derive some support from the sense of *muscular effort* of which we are conscious in making the exertion, and which we refer to the muscles which are concerned in it; but this sense of effort is nothing else than the 'muscular sense' already alluded-to, which has its origin in the state of tension of the muscles, and which is no more an indication of *mental* effort directed to them, than the sensation of light or sound is an indication of a determination of voluntary power to the eyes or ears.

546. There are two cases, already referred-to under another head, in which it is very easy to show that the Will is concerned with the result alone, and is not directly exerted upon the instruments by which that result is brought-about: these are, the movements of the Eyes, and the production of Vocal tones. In neither of them are we conscious of any effort in the muscular apparatus, unless the contraction be carried beyond its accustomed extent; the ordinary movements being governed, as already remarked, not by the muscular sense, but by the visual and auditory senses respectively.—Nothing can be more simple, to all appearance, than the act of turning the eyes upwards or downwards, to one side or the other, in obedience to a determination of the Will; and yet the Will does not impress such a determination upon the muscles. That which the Will really does, is to cause the eyeballs to roll in a given direction, in accordance with a visual sensation; and it is only *when there is an object* towards which the eyes can be turned, that we can move them with our usual facility. When the eyelids are closed, and we attempt to roll the globes upwards or downwards, to one side or to the other, we feel that we can do so but very imperfectly, and with a sense of effort referred to the muscles themselves,—this sense being the result of the state of tension in which the muscles are placed, by the effort to move the eyes without the guiding visual sensation. Now, on the other hand, the Will may determine to fix the eyes upon an object; and yet this very fixation may be only attainable by a muscular movement, which movement is

directly excited by the visual sense, without any exertion of voluntary power over the muscles. Such is the case when we look steadily at an object, whilst we move the head horizontally from side to side; for the eyeballs will then be moved in the contrary direction by a kind of instinctive effort of the external and internal recti, which tends to keep the retinæ in their first position, and to prevent the motion of the images over them. So, when we look steadily at an object, and incline the head towards either shoulder, the eyeballs are rotated upon their antero-posterior axis (probably by the agency of the oblique muscles) apparently with the very same purpose,—that of preventing the images from moving over the retinæ (see Chap. XIII., Sect. 3). Now we cannot refuse to this rotation any of the attributes which really characterize the so-called voluntary movements; and yet we are not even informed by our own consciousness that such a movement is taking place, but know it only by observation of others.

547. The muscular contractions which are concerned in the production of Vocal tones, are, in like manner, always accounted voluntary; and yet it is easy to show that the Will has no direct power over the muscles of the larynx. For we cannot raise or depress the larynx as a whole, nor move the thyroid cartilage upon the cricoid, nor separate or approximate the arytenoid cartilages, nor extend or relax the vocal ligaments, by simply *willing* to do so, however strongly. Yet we can readily do any or all these things, by an act of the Will exerted for a specific purpose. We conceive of a tone *to be* produced, and we *will* to produce it; a certain combination of the muscular actions of the larynx then takes place, in most exact accordance with one another; and the predetermined tone is the result. This anticipated or conceived sensation is the guide to the muscular movements, when as yet the utterance of the voice has not taken place; but whilst we are in the act of speaking or singing, the contractile actions are regulated by the present sensations derived from the sounds as they are produced.—It can scarcely but be admitted, then, that the Will does *not* directly govern the movements of the Larynx; but that these movements are immediately dependent upon some other agency.

548. Now what is true of the two preceding classes of actions, is equally true of all the rest of the so-called *voluntary* movements; for in each of them the power of the Will is really limited to the determination of the result; and the production of that result is entirely dependent upon the concurrence of a 'guiding sensation,' which is usually furnished by the very muscles that are called into action. It is obvious, therefore, that we have to seek for some intermediate agency, which *executes* the actions *determined* by the Will; and when the facts and probabilities already stated are duly considered, they tend strongly in favour of the idea, that even Voluntary movements are executed by the instrumentality of the Automatic apparatus, and that they differ only from the automatic or instinctive in the nature of the stimulus by which they are excited,—the determination of the Will here replacing, as the *exciting cause* of its action, the sensory impression which operates as such in the case of an instinctive movement, and which is still requisite for its guidance.

549. This view of the case derives a remarkable confirmation from the analysis of two classes of very familiar phenomena; the first consist

ing of cases in which movements that are ordinarily Automatic are performed by Voluntary determination, or simply in respondence to an Idea; the second consisting of those in which movements originally Voluntary come by habit to be Automatically performed.—Of the first class, the act of Coughing is a good example. This action, which is ordinarily automatic, may also be excited by a voluntary determination; such a determination, however, is directed to the *result*, rather than exercised in singling-out the different movements and then combining them in the necessary sequence; and the Will thus seems obviously to take the place of the laryngeal or tracheal irritation, as the *primum mobile* of the series, which, in its actual performance, is as automatic in the latter case as in the former. So, again, we know that many of the automatic movements which have been already referred-to as examples of the sensori motor group (§ 538), and which the Will cannot call-forth, may be performed in respondence to *ideas* or *conceptions*, which are Cerebral states that seem to recal the same condition of the Sensorium as that which was originally excited by the Sensory impression. Thus it is well known that the act of Vomiting may be induced by the *remembrance* of some loathsome object or nauseous taste, which may have been excited by some act of 'suggestion,' and the author has known an instance in which a violent fit of sea-sickness was brought-on by the sight of a vessel tossed about at sea, which recalled the former experience of that state. So, the Hydrophobic paroxysm may be excited by the mention of the *name* of water, which of course calls up the idea; and a tendency to yawn is in like manner frequently induced by looking at a picture of yawners, or by speaking of the act, or by voluntarily commencing the act which may then be automatically completed.—The automatic performance of actions which were originally voluntary, has already been fully discussed (§ 540); and we have therefore only to remark here, that the fact very strongly supports the view now advanced, as to the *singleness* of the mechanism which serves as the instrument of both classes of actions, and the essential uniformity of its operation in the two cases.—It would be difficult to explain either set of phenomena satisfactorily, on the hypothesis that there is a 'distinct system' of fibres for the volitional and for the automatic movements; since it is not readily to be conceived, how a set of movements originally performed by the one, can ever be transferred to the other; whilst, on the other hand, it is easy to understand how the same motorial action may be excited in the automatic centres, either by an *external* impression conveyed thither by an afferent nerve from a Sensory surface (as that of the irritation in the air-passages, which excites the act of coughing), or by a stimulus proceeding from the convoluted surface of the Cerebrum, and conveyed along those connecting fibres which Reil with great sagacity termed the 'nerves of the *internal* senses.'

550. To sum-up, then, we seem justified in concluding that the *Cranio-Spinal Axis* of Man and other Vertebrata,—consisting of the Sensory Ganglia, Medulla Oblongata, and Spinal Cord,—is (like the chain of cephalic and ventral ganglia of Articulata with which it is homologous) the immediate instrument of *all sensorial and motor changes;* that by its sole and independent action are produced all those movements which are ranked as *automatic* or *instinctive*, these being performed in respondence to external impressions which may or may not affect the consciousness;

but that when acting in subordination to the Cerebrum, the Cranio-Spinal Axis transmits upwards to it the influence of Sensorial changes and receives from it the downward impulses, which it directs automatically into the appropriate channel for the execution of the movements which the Mind has directed. The number of purely-automatic actions diminishes in proportion to the development of the Cerebrum, and to the subjection of the Automatic apparatus to its control; but even in Man, those most closely connected with the maintenance of the organic functions, or most necessary for the conservation of the bodily structure, remain quite independent of any mental agency, and most of them do not require consciousness for their excitation. But if the activity of the Cerebrum be suspended or be otherwise directed, without any affection of the automatic apparatus, movements which have long been habitually performed in a particular sequence, may be kept-up, when the will has once set them in action, through the automatic mechanism alone, the impressional or sensational change produced by each action, supplying the stimulus which calls-forth the next.—It may further be considered that the Sensory Ganglia, which are the instruments whereby we are rendered *conscious* of external impressions, are also the seat of those simple *feelings* of pleasure and pain, which are immediately linked with that consciousness; for it can scarcely be doubted that such feelings must be associated with particular sensations, in animals that have no ganglionic centres above these, since we must otherwise regard the whole series of Invertebrated tribes as neither susceptible of enjoyment nor capable of feeling pain or discomfort. And it likewise seems probable that the Sensory Ganglia are also the seat of those *perceptions* which bring the consciousness into direct relation with the external object that aroused the sensation (Sect. 6); since the recognition of *externality* seems evident in the actions of the tribes just referred to.

4. *Of the Cerebellum, and its Functions.*

551. The Cerebellum is an organ which, though confined to the Vertebrated sub-Kingdom, is yet in peculiarly intimate relation with the Automatic apparatus. In that highest state of development which it presents in Man, we find it to consist of two *lateral* lobes or *hemispheres*, composed of nerve-fibres invested in a very peculiar manner by vesicular substance, and of a *central* lobe, also containing a combination of the vesicular and fibrous substances, which is known under the designation of the 'vermiform process.' The hemispheres are connected with each other not only by this central lobe, but also by the fibrous commissure which passes beneath the Medulla Oblongata, and is known as the 'Pons Varolii.' The commissural fibres form part of the 'Crura Cerebelli,' but another portion is formed by the strands which connect the Cerebellum with the anterior and posterior columns of the Spinal Cord and Medulla Oblongata (§ 489), and in addition to these, we find a fasciculus of fibres passing between the Cerebellum and the Corpora Quadrigemina, the 'iter a cerebello ad testes.' The peduncle of its hemispheres on either side contains a mass of grey matter, the 'corpus rhomboideum,' or 'dentatum,' which seems to be a ganglionic centre for the fibres that pass upwards to it from the Spinal Cord. The Cerebellum has no direct connection with the Cerebrum, and its relations are entirely with the Cranio-Spinal Axis

552. When we examine into the relative development of the Cerebellum in the different classes of Vertebrata, we find that it presents some very remarkable differences.* In its simpler forms, this organ is found to consist entirely of the representative of the *central* lobe of the Human Cerebellum, the hemispheres not making their appearance until we have ascended to the class of Birds. On ascending the scale of Mammiferous animals, on the other hand, we cannot but be struck with the rapid advance in the proportional size of the Cerebellum, which we observe as we rise from the lowest (which are surpassed in this respect by many Birds) towards Man, in whom it attains a development which appears enormous, even when contrasted with that of the Quadrumana. In proportion, in fact, as the extremities acquire the power of prehension, and together with this a power of application to a great variety of purposes,—still more, in proportion as the animal becomes capable of maintaining the erect posture, in which a constant muscular exertion, consisting of a number of most elaborately combined actions, is required,—do we find the size of the Cerebellum, and the complexity of its structure, undergoing a rapid increase. Thus, even between the Dog and the Bear there is a marked difference; the latter being capable of remaining for some time in the erect posture, and often spontaneously assuming it; whilst to the former it is anything but natural. In the semi-erect Apes, again, there is a very great advance in the proportional size of the Cerebellum; and those which most approach Man in the tendency to preserve habitually the erect posture, also come nearest to him in the dimensions of this organ.—Thus on looking at the size of the Cerebellum, in relation to the general motor activity of the Vertebrated classes respectively, and especially taking into account the *variety* of their respective movements, and the number of separate muscular actions which are combined in each, we can scarcely help noticing that it is in the tribes which are most distinguished in these respects, that the largest Cerebellum is usually found. Now it is evident that Man, although far inferior to many of the lower animals in the power of performing various particular kinds of movement, far surpasses them all in the number and variety of the combinations which he is capable of executing, and in the complexity of the combinations themselves. Thus, if we attentively consider the act of *walking*, we shall find that there is scarcely a muscle of the trunk or extremities which is not actively concerned in it; some being engaged in performing the necessary movements, and others in maintaining the equilibrium of the body which is disturbed by them. On the other hand, in the Horse or Camel, the muscular movements are individually numerous, but they do not require nearly the same perfect co-ordination. And in the Bird, the number of muscles employed in the movements of flight, and in directing the course of these, is really comparatively small; as may at once be perceived, by comparing the rigidity of the skeleton of the trunk of the Bird with that of Man, and by remembering the almost complete inactivity of the lower extremities during the active condition of

* See "Princ. of Comp. Phys.," § 685.—Fuller information upon this point will be found in M. Serres' "Anat. Comp. du Cerveau," and M. Leuret's "Anat. Comp. du Système Nerveux."—For a general discussion of the evidence afforded by Comparative Anatomy in regard to the functions of the Cerebellum, see the "Brit. and For. Med. Rev.," vol. xxii. pp. 535–541.

the upper. In fact, the motions of the wings are so simple and regular as to suggest the idea, that, as in Insects, their character is more reflex than voluntary:—an idea which is supported by the length of time during which they can be kept-up without apparent fatigue, and also by the important facts already mentioned (§ 529), which experimental research has disclosed.

553. We have next to inquire what evidence can be drawn from Experimental investigations on the same subject; and in reference to this it is desirable to remark, in the first place, that the experimental mode of inquiry is perhaps more applicable to this organ than to other parts of the Encephalon; inasmuch as it can be altogether removed, with little disturbance of the actions immediately essential to life; and the animals soon recover from the shock of the operation, and seem but little affected except in some easily-recognized particulars. The principal experimenters upon this subject have been Rolando, Flourens, Magendie, Hertwig, and Longet. It is not to be expected, that there should be an exact conformity among the results obtained by all. Every one who has been engaged in physiological experiments, is aware of the amount of difference caused by very minute variations in their circumstances; in no department of inquiry is this more the case, than in regard to the Nervous System; and such differences are yet more likely to occur in experiments made upon its centres, than in those which concern its trunks. The investigations of Flourens* are the most clear and decisive in their results; and of these we shall accordingly take a general survey. He found that when the Cerebellum was mechanically injured, the animals gave no signs of sensibility, nor were they affected with convulsions. When the Cerebellum was being removed by successive slices, the animals became restless, and their movements were irregular; and by the time that the last portion of the organ was cut-away, the animals had entirely lost the power of springing, flying, walking, standing, and preserving their equilibrium,—in short, of performing any combined muscular movements which are not of a simply-reflex character. When an animal in this state was laid upon the back, it could not recover its former posture; but it fluttered its wings and did not lie in a state of stupor. When placed in the erect position, it staggered and fell like a drunken man,—not, however, without making efforts to maintain its balance. When threatened with a blow, it evidently saw it, and endeavoured to avoid it. It did not seem that the animal had in any degree lost voluntary power over its several muscles; nor did sensation appear to be impaired. The faculty of *combining* the actions of the muscles in groups, however, was completely destroyed; except so far as those actions (as that of Respiration) were dependent only upon the reflex function of the Spinal Cord. The experiments afforded the same results, when made upon each class of Vertebrated animals; and they have been since repeated, with corresponding effects, by Bouillaud and Hertwig. The latter agrees with Flourens, also, in stating that the removal of one side of the Cerebellum affects the movements of the opposite side of the body; and he further mentions that, if the mutilation of the Cerebellum have been partial, its function is in great degree restored.†

* "Recherches Expérim. sur les propriétés et les fonctions du Système Nerveux."

† All these results are objected-to by those who assert that the Cerebellum is the seat of

554. It was further affirmed by Magendie, that the removal of the Cerebellum, or the infliction of a deep wound in its substance on both sides, occasions the animal to move *backwards* as it by an irresistible impulse; and this he attributed to the retrograde power of the Corpora Striata, which now acts without its due balance. That such a movement does *sometimes* present itself after such injuries as have been described, cannot be questioned, the fact having been confirmed by other experimenters; but it is a phenomenon of such rarity, that it cannot be rightly considered as having any direct dependence upon the injury of the Cerebellum, but must be rather set-down to some accidental complication or concurrent disturbance; more especially since, as already pointed-out (§ 533), the function attributed by Magendie to the Corpora Striata has no real existence.—But the results of section of one of the Crura Cerebelli, which were first obtained by Magendie, are much more constant; for the performance of this operation causes the animal to fall-over upon one side, and to continue *rolling upon its longitudinal axis*, even as fast (in some instances) as sixty times in a minute, the movement going-on for many days without intermission. There is a remarkable difference in the statements of different experimenters, however, as regards the direction of this rolling movement; for whilst Magendie and Muller affirm that it takes place *towards* the injured side, Longet and Lafargue assert that it takes place *from* the injured side towards the opposite side. This discrepancy appears, from the experiments of Schiff,* to be due to a difference in the locality of the section; for he states that if the peduncle be divided from *behind*, the animal turns *towards* the side on which the section is made; whilst if the section be made *in front*, the animal turns *from* that side towards the opposite one. This difference is explained by Longet, by the difference in the course of the anterior and posterior fibres of the peduncles: for according to him, the former communicate with the decussating, and the latter with the non-decussating portion of the motor tract; so that, when the former are injured, the animal loses control over the muscles of the opposite side, and when the latter, over the muscles of the same side. This rolling movement is attributed by some to the continued activity of the muscles on one side, now unbalanced by that of the muscles on the other; but if such were the case, as Longet justly remarks, it ought to occur more frequently than it does in cases of ordinary hemiplegia; and, according to that experimenter, observation shows that it rather depends on a *twisting* movement of the spinal column, especially affecting its anterior portion, and dragging the posterior (as it were) after it.†

555. The information supplied by Pathological phenomena, when interpreted with the cautions formerly referred-to, is found on the whole to coincide with that obtained from experiment. In the first place, it fully supports the conclusion, that the Cerebellum is not in any way the

the sexual instinct, on the ground that the observed aberrations of the motor functions are sufficiently accounted for, by the general disturbance which an operation so severe must necessarily induce. The fallacy of this objection, however, is shown by the fact, that the much more severe operation of removing the Hemispheres does not occasion such an aberration; the power of performing the associated movements, and of maintaining the equilibrium, being remarkably preserved after the loss of them (§ 529).

* "De vi motoria baseos encephali inquisitiones experimentales." Bockenheim, 1845.

† See his "Traité de Physiologie," tom. ii., partie 2, pp. 216, 217.

instrument of *psychical* operations. Inflammation of the membranes covering it, if confined to that part, does not produce delirium; and its almost complete destruction by gradual softening, does not appear necessarily to involve loss of intellectual power. "But," remarks Andral, "whilst the changes of intelligence were variable, inconstant, and of little importance, the lesions of motion, on the contrary, were almost constant in all the cases [of softening] except one; and in this it is not quite certain that motion was not interfered with." Yet the result of Andral's analysis of as many as ninety-three cases of disease of the Cerebellum,* is not favourable to the doctrine to which the results of experiments seem to point: but, as it has been justly remarked by Longet, the effects of disease are only partly comparable to those of experiment; since in a large proportion of chronic disorders, the changes consist in the formation of a new product, such as a tubercular or cancerous deposit, or a cyst of some kind, the gradual development of which is quite compatible with the continued functional activity of the organ, as we see by parallel phenomena elsewhere; whilst in those instances in which hemorrhage occurs, this usually occasions either complete apoplexy or local paralysis by its effects upon other organs. Still, several cases of chronic disease of the Cerebellum have been observed, in which *unsteadiness of gait*, without paralysis, or only giving place to paralysis at last on the occurrence of hemorrhage, was a very marked symptom;† and these afford a strong confirmation of the doctrine based on the experimental researches already referred-to. In a few cases in which both lobes of the Cerebellum have been seriously affected, the tendency to retrograde movement has been observed; and instances are also on record, of the occurrence of rotatory movement, which has been found to be connected with lesion of the Crus Cerebelli on the same side.‡ So far as they can be relied on, therefore, the results of the three methods of investigation bear a very close correspondence; and it can scarcely be doubted that they afford us a near approximation to truth.

556. It must not be allowed to pass unnoticed, that some Physiologists (as Foville, Pinel-Grandchamp, and Dugès) have regarded the Cerebellum as the centre of common Sensation; chiefly on the ground of its connection with the posterior columns of the Spinal Cord, and of the manifestations of pain which are called-forth by touching the Restiform columns. Although these facts may lead us to admit that the Cerebellum is connected with the sensorial centres, and even that it is itself a seat of sensibility, yet it is impossible to regard it as the exclusive seat of sensibility, consistently with the facts with which experiment and pathological observation supply us; since neither the removal of the

* See his "Clinique Médicale," 2ème edit. tom. v. p. 735.

† Two such cases are recorded by Mr. Dunn in the "Med.-Chir. Trans.," vol. [illegible] and another by Dr. Cowan in the "Prov. Med. and Surg. Journ.," April 1[illegible], [illegible]; and the Author has been made acquainted with several others, by gentlemen under whose cognizance they have fallen.

‡ A collection of such cases has been made by Dr. Paget, in his paper on 'Unusual Rhythmical Movements,' in the "Edinb. Med. and Surg. Journal," 1847, and likewise a case fell within the Author's knowledge a few years ago, in which a state of this kind that lasted for some hours, appeared to depend upon an attack of Indigestion, the symptoms being completely relieved by vomiting, and no further indication of Encephalic disease manifesting itself.

entire organ by operation, nor its complete destruction by disease,* have been found to involve any loss of the ordinary sensorial powers. There would seem much more probability in the idea, that it is the special seat of the 'muscular sense,' which has so important a share in the guidance of the co-ordinated movements (§ 541); and this notion derives confirmation from the marked structural connection which exists between the Cerebellum and the Optic Ganglia (corpora quadrigemina), the purpose of which may be not unfairly surmised to be, to communicate the guidance of the *visual* sense to the organ by which the co-ordination of motions is effected, in the same manner as the impressions appertaining to the 'muscular sense' are transmitted upwards by the Restiform columns. The chief objection to such a view, would seem to lie in the strong similarity between the 'muscular' sense and 'common' or 'tactile' sensation, which makes it difficult to conceive that they should have different seats in the *Sensorium commune*. But this difficulty is diminished if not removed by the reflection, that the Restiform columns appear to have the same endowments as the remainder of the Sensory tract derived from the posterior columns of the Spinal Cord; and that no explanation can be given of their extreme sensitiveness to impressions (as shown by experiment), unless it be admitted that the organ in which they terminate is itself a centre of a form of sensation closely allied to that of the common or tactile kind. Possibly, however, the true termination of these fibres is in the 'corpus dentatum' of the Crura Cerebelli; and the Cerebellum may re-act upon impressions thence transmitted to it, without being itself the instrument of communicating such impressions to the consciousness.

557. We have now to examine, however, another doctrine regarding the functions of the Cerebellum, which was first propounded by Gall, and which is supported by the Phrenological school of physiologists. This doctrine, that the Cerebellum is the organ of the sexual instinct, is not altogether compatible with the other; and by some it has been held in combination with it. The greater number of Phrenologists, however, regard this instinct as the *exclusive* function of the Cerebellum; and assert that they can judge of its intensity, by the degree of development of the organ. We shall now examine the evidence in support of this position, afforded by the three methods of inquiry which have been already indicated.—In the first place it may be remarked, that the sexual propensity is very closely connected with various Emotional states of mind, to which 'organs' are assigned by Phrenologists, and of which the Cerebrum is universally admitted to be the seat, such for instance as 'love of offspring,' 'adhesiveness,' and (in the lower animals more particularly) 'combativeness;' whilst in Man it has a continual operation upon the reasoning faculties and the Will. Yet the anatomical connections of the Cerebellum are peculiarly unfavourable to any such influence; these being, as we have seen rather with the lower than with the higher portion of the Cerebro-spinal axis.—Again, the results of fair observation as to the comparative size of the Cerebellum in different animals, can scarcely be regarded as otherwise than very unfavourable to the doctrine in question.†—It is asserted, however, that the results of observation in

* See the well known case recorded by Combette, in the "Revue Médicale," tom. ii p 57.

† See "Brit. and For. Medical Review," vol. xxii. pp. 535–541.

Man lead to a positive conclusion, that the size of the Cerebellum is a measure of the intensity of the sexual instinct in the individual. This assertion has been met by the counter-statement of others, that no such relation exists. It is unfortunate that here, as in many other instances, each party has registered the observations favourable to its own views, rather than those of an opposite character; so that until some additional evidence of a less partial nature shall have been collected, we must consider the question as *sub judice*. It may be safely affirmed, however, that no evidence upon the affirmative side of this proposition has yet been adduced, which can be in the least degree satisfactory to the mind of any Anatomist who is competent to judge of its value. For nearly all the observations which have been paraded by Phrenologists in support of Gall's doctrine, have been based, *not* upon the actual *determination* of the size or weight of the Cerebellum in different individuals, but upon an *estimate* of its proportional development from the external conformation of the skull. Now any one who has even cursorily examined those principal types of cranial conformation, which are characteristic of some of the chief subdivisions of the Human species, must perceive that there is a no less characteristic difference between these different types in the occipital, than there is in the frontal region. For whilst the occipital projection is much *greater* in the 'prognathous' skull than it is in the 'elliptical,' it is as much *less* in the 'pyramidal,' and thus while the first would be considered, according to phrenological rules, to hold a much larger Cerebellum, this organ in the latter would be regarded as necessarily very small. Now there is not only as much evidence of a strong development of the sexual propensity, in the characters and habits of the pyramidal-skulled Asiatics, as there is in regard to the elliptical-skulled Europeans, or the prognathous Negroes; but there is also anatomical evidence to show that *the size of the Cerebellum in the different races bears no relation whatever to the degree of projection of the occiput*; for the plane of this organ being somewhat oblique in the elliptical skull, is horizontal in the prognathous, and nearly vertical in the pyramidal, while the size and anatomical relations of the organ are not in the least degree affected by this difference in its position.*—Hence it may be safely affirmed, that no evidence with regard to the relation asserted to exist between the size of the Cerebellum and the intensity of the sexual propensity, has any value, save that which is drawn from the positive determination of the former by measure or weight.

558. Among the arguments adduced by Gall and his followers in proof of the connection between the Cerebellum and the sexual instinct, is one which would deserve great attention, if the facts stated could be relied-on. It has been asserted, over and over again, that the Cerebellum, in animals which have been castrated when young, is much smaller than in those which have retained their virility,—being, in fact, *atrophied* from want of power to act. Now it is unfortunate that vague assertion, founded on estimates formed by the eye from the cranium alone, is all on which this position rests; and it will be presently shown how very liable to error such an estimate must be. The following is the result of a series of

* The Author's statements on this point are based on the very decided assertions of his friend Prof. Retzius of Stockholm, who has paid special attention to this inquiry.

observations on this subject, suggested by M. Leuret,* and carried into effect by M. Lassaigne:—The *weight* of the Cerebellum, both absolutely, and as compared with that of the Cerebrum, was adopted as the standard of comparison. This was ascertained in ten Stallions, of the ages of from nine to seventeen years; in twelve Mares, aged from seven to sixteen years; and in twenty-one Geldings, aged from seven to seventeen years. The average weight of the Cerebrum in the *Stallions* was 433 grammes; the greatest being 485 gr., and the least (which was in a horse of ten years old) being 350 gr. The average weight of the Cerebellum was 61 gr.; the greatest being 65 gr., and the least 56 gr. The average proportion borne by the weight of the Cerebellum to that of the Cerebrum, was, therefore, 1 to 7·07; the highest (resulting from a very small Cerebrum) being 1 to 6·25; and the lowest (resulting from an unusually large Cerebrum) being 1 to 7·46. Throughout it might be observed, that the variation in the size of the Cerebellum was much less than in that of the Cerebrum.—In the twelve *Mares*, the average weight of the Cerebrum was 402 gr., the highest being 432 gr., and the lowest 363 gr. That of the Cerebellum was 61 gr.; the highest being 66 gr. (which was in the individual with the smallest Cerebrum), and the lowest 58 gr. The average proportion of the weight of the Cerebellum to that of the Cerebrum was 1 to 6·59; the highest being 1 to 5·09, and the lowest 1 to 7. The proportion was, therefore, considerably higher in the perfect female, than in the perfect male.—In the twenty-one *Geldings*, the average weight of the Cerebrum was 419 gr.; the highest being 566 gr., and the lowest 346 gr. The average of the Cerebellum was 70 gr.; the highest being 76 gr., and the lowest 64 gr. The average proportion was, therefore, 1 to 5·97; the highest being 1 to 5·16, and the lowest 1 to 7·44. It is curious that this last was in the individual which had the largest Cerebellum of the whole; but the proportional weight of the Cerebrum was still greater.—Bringing together the results of these observations, they are found to be quite opposed to the statement of Gall. The weight of the Cerebrum, reckoning the Cerebellum as 1, is thus expressed in each of the foregoing descriptions of animals:—

	Average.	*Highest.*	*Lowest.*
Stallions	7·07	7·46	6·25
Mares	6·59	7·00	5·09
Geldings	5·97	7·44	5·16

The average *proportional* size of the Cerebellum in Geldings, therefore, is so far from being *less* than that which it bears in entire Horses and Mares, that it is positively greater; and this depends not only on diminution in the relative size of the Cerebrum, but on its own larger dimension, as the following comparison of *absolute* weights will show:—

	Average.	*Highest.*	*Lowest.*
Stallions	61	65	56
Mares	61	66	58
Geldings	70	76	64

The difference is so remarkable, and appears, from examination of the individual results, to be so constant, that it cannot be attributed to any accidental circumstance, arising out of the small number of animals

* "Anat. Comp. du Système Nerveux," tom. i. p. 427.

thus examined. The average weight of the Cerebellum in the ten Stallions and twelve Mares, is seen to be the same, and the extremes differ but little in the two; whilst the average in the Geldings is more than one-seventh higher, and the *lowest* is considerably above the *average* of the preceding, while the highest far exceeds the highest among the entire Horses. It is curious that Gall would have been much nearer the truth, if he had said that the dimensions of the *Cerebrum* are usually reduced by castration; for it appears from the following table that such is really the case:—

	Average.	*Greatest.*	*Least.*
Stallions	443	485	350
Mares	402	432	336
Geldings	419	566	346

The weight of the largest Cerebrum of the Gelding is far above the highest of the Stallions; but it seems to have been an extraordinary case, as in no other was the weight above 490 gr. If this one be excluded, the *average* will be reduced still further, being then about 412; this may be seen, by looking over the whole table, to give a very fair idea of the usual weight in these animals, which is therefore *less*, by about one-twentieth, than the average in the Stallions.—The increased size of the Cerebellum in Geldings may perhaps be accounted for, by remembering that this class of horses is solely employed for its muscular power, and that the constant exercise of the organ is not unlikely to develope its size; whilst Stallions, being kept especially for the purpose of propagation, are much less applied to occupations which call forth their motor activity.

559. It is asserted, however, by the followers of Gall, that very strong evidence of the truth of his doctrine is afforded by Pathological phenomena: excitement of the genital organs, manifesting itself in priapism, turgescence of the testes, and seminal emissions, being an ordinary concomitant of some forms of apoplexy in which the Cerebellum is affected; whilst in other cases of disease or injury involving extensive destruction of the substance of the organ, there has been a complete abatement of sexual desire. The proportion of recorded cases of disease of the Cerebellum, however, in which any affection of the genital organs has been noticed, is extremely small; for out of 178 cases which have been collected by Burdach,* only 10, or scarcely more than 1 in 18, presented any symptoms that tended to indicate a functional relation between the Cerebellum and the Genital organs. The same physiologist affirms that similar affections present themselves, when the Cerebrum is the seat of the lesion; and there seems a strong probability that it is solely to the connection of these organs with the Spinal Cord, that such affections of the genital apparatus are due. For erection of the penis has been noticed in a far larger proportion of cases in which the Spinal Cord itself has been the seat of the lesion; thus in 15 cases in which the cervical portion of the Cord was affected, erection of the penis was observed in 8; and in 13 cases of lesion of the dorso-lumbar portion of the cord, erection of the penis took place in 3.† It is well known that

* "Von Baue und Leben des Gehirns," (Leipzig, 1819-26), band iii.

† See the "Traite des Maladies de la Moelle Epiniere" of M. Ollivier (d'Angers), 3ième edit., tom. iii. p. 316

erection of the penis and emissio seminis are not infrequent phenomena of death by hanging; and this fact accords fully as well with the idea that the affection of the sexual organs is consequent upon lesion of the Cranio-Spinal axis, as with the doctrine that it is due to disordered function of the Cerebellum.—It has been suggested by Serres,* who collected seven cases in which excitement of the genital organs was coincident with apoplexy of the median lobe of the Cerebellum, that whilst the lateral lobes or hemispheres may be connected with the locomotive function, the median lobe may be the organ of the sexual instinct. Several cases have been recorded, in which some such relation appeared to be indicated; and the Author has been made acquainted with at least six,† in which an extraordinary salacity developed itself at an advanced period of life, whilst, concurrently with this, or following upon it, there was that kind of unsteadiness of gait which may be held to indicate chronic disease of the Cerebellum. In one of these cases, of which the history and post-mortem appearances have been carefully recorded by Mr. Dunn,‡ there was strong evidence that the excitement of the sexual propensity was coincident with the irritative stage of incipient disease in the central lobe of the Cerebellum, and that the abatement of the propensity was in like manner coincident with the subsequent destruction of its substance; whilst the advance of the disease into the lateral lobes was marked by impairment of the power of co-ordination of movement. But with regard to all such cases, and others that may be ranked in the same category,§ the objection of Pétrequin‖, holds good, that when disease or injury affects the median lobe of the Cerebellum, the Medulla Oblongata is almost certain to be implicated in it; so that, as the evidence already referred-to clearly indicates the existence of a special relation between the genital organs and the upper part of the Spinal Axis, no positive proof is afforded by them that any portion of the Cerebellum has any special connection with the generative function.

560. The Author is far from denying *in toto*, that any peculiar connection exists between the Cerebellum and the Genital system; but if the evidence at present adduced in support of the Phrenological position be held sufficient to establish it, in defiance of so many opposing considerations, we must bid adieu to all safe reasoning in Physiology. The weight of testimony appears to him to be quite decided, in regard to the connection of the Cerebellum with the regulation of the motor function; and as an additional argument in favour of this view, it may be stated, that the

* "Anatomie Comparée du Cerveau," tom. ii. pp. 601, 717.

† Four such cases have come under the notice of his friend Dr. Simpson of York.

‡ "Medico-Chirurgical Transactions," vol. xxxii.

§ Thus, a case has been communicated to the Author by Mr. Turley of Worcester, in which the sexual desire, which had been always strong through life, but which had been controlled within the limits of decency, manifested itself, during a period of some months preceding death, in a most extraordinary degree; on *post mortem* examination, a tumour was found on the Pons Varolii. And he has been informed of another case by Dr. Evanson formerly of Dublin, in which a young officer on the eve of marriage, having received a blow on the occiput by a fall from his horse, became impotent, without any other disorder of his bodily or mental powers; and in the distress consequent upon this discovery, committed suicide on the morning fixed for his wedding.

‖ "Sur quelques points de la Physiologie du Cervelet et de la Moëlle Epinière," in "Gaz. Médicale," 1836, tom. iv. p. 548.

lobes of the Human Cerebellum undergo their most rapid development during the first few years of life, when a large number of complex voluntary movements are being learned by experience, and are being associated by means of the muscular sensations accompanying them; whilst in those animals which have, immediately after birth, the power of regulating their voluntary movements for definite objects, with the greatest precision, the Cerebellum is more fully developed at the time of birth. In both instances it is well formed and in active operation, so far as can be judged of by the amount of circulation through it, long before the sexual instinct manifests itself in any perceptible degree.— But neither doctrine need be maintained altogether to the exclusion of the other; and there are many among the Phrenologists of the present day, who hold, with Serres, that whilst the *hemispheres* of the Cerebellum possess the endowments now generally assigned to them by Physiologists, the *central lobe* is connected with the Genital function. It has been shown by Dr. N. S. Davis,* however, that there is no perceptible difference in the dimensions of this central lobe, any more than in those of the hemispheres, between Bulls and Oxen; and no proof has yet been offered, save that afforded by the pathological evidence just referred to, that any such endowment is possessed by it. That in some way or other, however, either the central portion of the Cerebellum, or some part of the Medulla Oblongata, has a special connection with the Generative function, appears to the Author to be indicated with tolerable clearness by several of the Pathological phenomena already cited. The circumstance, too, of which he has frequently been assured, that great application to gymnastic exercises diminishes for a time the sexual vigour and even totally suspends desire, seems worthy of consideration in reference to such a view; for if the Cerebellum be really connected with both kinds of function, it does not seem unreasonable that the excessive employment of it upon one should diminish its energy in regard to the other.—An analysis of the nature of the Sexual propensity, however, suggests the conclusion that we are not to look in this part of the Encephalon for anything else than a seat of the sexual *sensation*; the character of which seems to be sufficiently different from that of mere *tactile* sensation, to require a distinct ganglionic centre. Such a centre would be likely to be placed in the line of the other sensory ganglia, and in close connection with them.

561. As in the case of other sensations, the Sexual, when moderately excited, may give rise to ideas, emotions, and desires, of which the Cerebrum is the seat; and these may react on the muscular system through the Intelligence and Will. But when inordinately excited, or when not kept in restraint by the Will, the sexual sensations will at once call into play respondent movements, which are then to be regarded as purely automatic; this is the case in Nymphomania and Satyriasis in the Human subject; and it is probably also the ordinary mode of operation of this sense, in such of the lower animals as have not psychical power enough to form a conception of an absent object of gratification, and cannot therefore, be said to have sexual *desires*. Thus, like other sensations, it may act either *intelligentially* or *automatically*, giving rise to *ideas*, or

* 'Transactions of American Medical Association,' vol. iii. p. 415.

transmission to the Cerebrum, which ideas, associated with pleasurable feelings, originate *desires* that stimulate the Reasoning powers to devise means for their gratification, and excite the Will to the necessary actions; or, by its immediate action upon the motor apparatus, producing respondent *movements*. Of this double *modus operandi* we seem to have sufficient evidence. For among many of the lower tribes of animals, at the time when the generative organs are in a state of functional activity, the presence of an individual of the opposite sex, indicated by the sight, smell, hearing, or touch, immediately excites the whole train of instinctive actions concerned in the reproductive operation; whilst we have no evidence in them of any voluntary exertion, resulting from the existence of a desire entertained in the absence of the object, and intended for the gratification of that desire. In Man, on the other hand, the principal operation of the sexual sensations is in awakening desires and affections, which serve as excitements to the intelligence and as motives to the Will; and it is only, under ordinary circumstances, when the two sexes have been thus brought into close relation, that the direct reaction of the sexual sensation manifests itself in automatic movements. In cases, however, in which this sensation is excited in unusual strength, it may completely overmaster all motives to the repression of the propensity, and may even entirely remove the actions from volitional control; and a state of a very similar kind exists in many Idiots, in whom the sexual propensity exerts a dominant power, not because it is in itself peculiarly strong, but because, the Intelligence being undeveloped, it acts without restraint or direction from the Will.

5. *The Cerebrum, and its Functions.*

562. We come, in the last place, to consider the functions of that portion of the Nervous Centres, which is evidently, in Man, the predominant organ of his whole system; being not merely the instrument of his Reasoning faculties, but also possessing a direct or indirect control over nearly all the actions of his corporeal frame, save those purely vegetative processes which are most completely isolated from his animal powers. We should be in great danger, however, of coming to an erroneous conclusion as to the real character of the Cerebrum and of its operations, if we confined ourselves to the study of the Human organism; and the history of Physiological science shows, that every advance of knowledge respecting its functions has tended to *limit* them, whilst at the same time rendering them *more precise*. Thus the Brain (this term, in the older Anatomy, being chiefly appropriated to the Cerebrum) was once accounted, not merely the centre of all motion and sensation, but also the source of all vitality; the different processes of nutrition, secretion, &c., being maintained, it was supposed, by a constant supply of 'animal spirits,' propagated from the brain, along the nerves, to each individual part. The more modern doctrine, that the Sympathetic System has for its special function to supply the nervous influence requisite for the maintenance of the functions of Organic life, was the first step in the process of limitation; still the Brain was regarded as the centre of all the Animal functions, and no other part was admitted to possess any power independently of it. By experiments and pathological observations, however, the powers of

the Spinal Cord as an independent centre of action were next established and it was thus shown that there is a large class of motions in which the Brain has no concern, and that the removal of the Cerebral hemispheres is not incompatible (even among the higher Vertebrata) with the prolonged maintenance of a sort of inert and scarcely conscious life. Still it has been usually maintained, and with great show of reason, that the Cerebrum is the instrument of all *psychical* operations, and the originator of *all* the movements which could not be assigned to the reflex action of the Spinal Cord. An attempt has been made, however, in the preceding pages, to show that this view is not correct, and that there is a class of actions, neither excito-motor nor voluntary, but directly consequent upon Sensations, and constituting (with the excito-motor) the truly *instinctive* actions, which may be justly assigned to certain ganglionic centres not less independent of the Cerebrum than is the Spinal Cord itself. It has been further pointed-out, that the Cerebrum must be considered in the light of an organ *superadded* for a particular purpose or set of purposes, and not as one which is essential to life, that it has no representative among the Invertebrata (except in a few of the highest forms, which evidently present a transition towards the Vertebrated series); and that, at its first introduction in the class of Fishes, it evidently performs a subordinate part in the general actions of the Nervous System. Hence, whatever be the function, or set of functions, we assign to the Cerebrum, we must keep in view the *special* character of the organ; and must never lose sight of the fact, that its predominance in Man does not deprive other parts of their independent powers, although it may keep the exercise of those powers in check, and may considerably modify their manifestations.

563. Before proceeding to inquire into the Physiology of the Cerebrum, we may advantageously take notice of some of the leading features of its structure.—In the first place, it forms an exception to the general plan on which the elements of ganglionic centres are arranged, in having its vesicular substance on the *exterior*, instead of in the *central* part of the mass. The purpose of this is probably to allow the vesicular matter to be disposed in such a manner, as to present a very large *surface*, instead of being aggregated together in a more compact mass, and by this means to admit, on the one side, a more ready access of the blood-vessels which are so essential to the functional operations of this tissue, as well as a more ready communication, on the other, with the vast number of fibres by which its influence is to be propagated. There is no reason whatever to believe, that the relative functions of the vesicular and fibrous substances are in the least altered by this change in their relative position; indeed, the results of observation upon the phenomena of disordered Cerebral action are such, as to afford decided confirmation to the doctrine now generally accepted, that the action of the Vesicular matter constitutes the *source* of nervous power, whilst the Fibrous structure has for its office to *conduct* the influence thus generated to the points at which it is to operate. The purpose of this arrangement is further evidenced by the fact, that, in all the higher forms of Cerebral structure, we find a provision for a still greater extension of the surface at which the vesicular matter and the blood vessels may come into relation; this being effected by the plication of the layer of vesicular matter into 'convolutions' into the sulci between which, the highly vascular membrane known as

the 'pia mater' dips-down, sending multitudes of small vessels from its inner surface into the substance it invests.

564. The *Cortical* substance or 'grey matter' of the Hemispheres essentially consists of that *vesicular* nerve-substance, which, in the Spinal Cord, as in ganglionic masses generally, is found to occupy the interior. Its usual thickness is about one-fifth of an inch; but considerable variations present themselves in this respect, as also in the depth of the convolutions. Thus the plications are deepest, and the layer of 'grey matter' the thickest, during the period of greatest nervous energy, that is, in middle life; in infancy and in old age, the convolutions are simpler and have fewer undulations, and the thickness of their cortical substance is much inferior; and the same is true of the adult brain of some of the least cultivated races of mankind. Three layers of somewhat different hues may be distinguished in the cortical substance; the external, *white*, the middle, *pure grey*, the internal, *yellowish red*. The latter, however, may generally be subdivided into four; namely, two white laminæ, alternating with two yellowish red laminæ. Throughout its entire thickness, however, nerve-cells and nerve-fibres are intermixed; and these are imbedded in a granular matrix-substance. The nerve-cells are for the most part remarkable for the number of pale slender branching processes which they give-off; and it may be strongly suspected, though it has not been unequivocally proved by observation, that these are continuous with some (at least) of the fibres which are found in close relation to them. These cells are most abundant in the middle or pure-grey layer, and next to this in the internal or yellowish-red layer; on the other hand, in the external white layer, and in the white streaks of the internal layer, the fibres spread-out in a plane that is nearly parallel to the surface. The further the fibres penetrate from the medullary stratum into the cortical substance, the finer do they become; and in the external white lamina, in which they form numerous superimposed layers, and cross each other in various directions, they are reduced to their very smallest dimensions. It seems certain that both in this and also in the grey layer, *some* of the fibres return by loops; although it has not been yet found possible to determine to what order of fibres these belong.*

565. In the *Medullary* or *fibrous* substance, of which the great mass of the Cerebrum is composed, three principal sets of fibres may be distinguished. These are,—*first*, the radiating fibres, which connect the vesicular matter of the cortical substance of the Hemispheres with the Thalami Optici, and which, if our view of the function of the latter be correct, may be regarded as *ascending*;—*second*, the radiating fibres which connect the vesicular matter of the cortical substance of the Hemispheres with the Corpora Striata, and which, on similar grounds, may be regarded as *descending*,—and *third*, the Commissural fibres, which establish the connection between the opposite Hemispheres, and between the different parts of the vesicular substance of the same side, especially between that disposed on the surface of each hemisphere, and those isolated patches which are found in its interior. It is on the very large proportion which the Commissural fibres bear to the rest, that the bulk of the Cerebrum of Man and of the higher animals seems

* See Prof. Kolliker's "Manual of Human Histology," (Syden. Soc.), vol. i pp. 439–443; and his "Mikroskopische Anatomie," band ii. § 119

chiefly to depend; and it is easy to conceive, that this condition has an important relation with the operations of the Mind, whatever be our view of the relative functions of different parts of the Cerebrum. It appears from the late researches of M. Baillarger, that the *surface* and the *bulk* of the cerebral hemispheres are so far from bearing any constant proportion to each other, in different animals, that, notwithstanding the depth of the convolutions in the Human Cerebrum, its bulk is 2[illegible] times as great in proportion to its surface, as it is in the Rabbit, the surface of whose Cerebrum is smooth. The entire surface of the Human Cerebrum is estimated by him at about 670 square inches.*

566. With regard to the *Radiating* fibres, which connect the Corpora Striata and Thalami Optici with the vesicular surface of the Cerebral

FIG. 90.

Diagram of the mutual relations of the principal Encephalic centres, as shown in a vertical section:—A, Cerebrum; B, Cerebellum; C, Sensory ganglia or tract, including the Olfactory ganglion *olf*, the Optic *opt*, and the Auditory *aud*, with the Thalami Optici *th*, and the Corpora Striata *cs*; D, Medulla Oblongata; E, Spinal Cord; [illegible] *d*, pneumogastric; *e*, hypoglossal; *f*, spinal. [illegible] fibres of the [illegible] of the Cerebrum are shown, connecting its ganglionic surface with the Sensori-motor tract.

hemispheres, not only has no positive proof yet been obtained of their direct continuity with those which enter into the composition of the nerves proceeding from the Spinal Cord and Medulla Oblongata, but the results of the most recent and careful examination are in opposition to such an idea (§ 519). And we have seen that there are certain

* The inference drawn by M. Baillarger from the facts he has collected, that the proportional surface of vesicular matter in different animals, whether considered absolutely, or relatively to the volume of the Cerebrum, has no correspondence with their intellectual capability, is far too sweeping an assumption; since, as above shown, an increase in the commissural fibres, causing an augmentation of the bulk of the Cerebrum, may be alike the cause of increased intelligence and of a diminished proportional amount of vesicular matter, though the latter still remains as the original source of power.

phenomena, which are best explained by considering these radiating fibres as of a *commissural* nature only; and as serving to connect the vesicular matter of the Cerebrum with that of the higher portions of the *Cranio-Spinal Axis*, through which alone they are brought into relation with the central terminations of the afferent nerves, and with origins of the motor (§ 544). Thus the Anatomical relation which the grey matter of the Cerebral convolutions bears to the central Sensorium, precisely corresponds with that which is borne to it by the Retina, which essentially consists, like it, of an expansion of vesicular substance (§ 754); whilst the radiating fibres of the medullary substance answer precisely to the Optic Nerve. And it is a most important confirmation of this view, that such a relation is also shown to exist by the history of Development. For the cortical substance of the Cerebrum and the Retina alike originate as offsets from the Sensory Ganglia, the former detaching itself from the Corpus Striatum on either side, the latter from the Thalamus Opticus; and each being gradually removed to a greater and greater distance from its original centre, by the elongation of the intervening commissural tract. It seems to have been a kind of recognition of this analogy, which long since led the sagacious Reil to designate the Cerebral lobes as a congeries of 'nerves of the internal senses.'*

567. The *Commissural* fibres constitute two principal groups, the *transverse*, and the *longitudinal*, the former connecting the two Hemispheres with each other; the latter uniting the different parts of the same Hemisphere.—Of the transverse commissures, the *Corpus Callosum* is the most important. This consists of a mass of fibres very closely interlaced together; which may be traced into the substance of the hemispheres on each side, particularly at their lower part, where their connections are the closest with the Thalami Optici and Corpora Striata. It is difficult, if not impossible, to trace its fibres any further; but there can be little doubt that they radiate, with the fibres proceeding from the bodies just named, to different parts of the cortical substance of the Hemispheres. This commissure is altogether wanting in Fish, Reptiles, and Birds; and it is partially or completely wanting in those Mammals whose Cerebrum is formed upon the least complex plan,—the Rodents and Marsupials. Although the *Anterior* commissure particularly unites the Corpora Striata of the two sides, many of its fibres pass through those organs, and radiate towards the convolutions of the Hemispheres, especially those of the middle lobe; this commissure is particularly large in those Marsupials, in which the Corpus Callosum is deficient.—Of the *longitudinal* commissures, some lie above, and others below, the Corpus Callosum. Upon the transverse fibres of that body, there is a longitudinal tract on each side of the median line, which serves to connect the convolutions of the anterior and posterior Cerebral lobes. Above this, again, is the *Superior longitudinal* commissure, which is formed by the fibrous matter of the greater convolutions nearest the median plane on the upper surface of the Cerebrum, and which connects

* He says, "The nerves of the external senses and voluntary muscles escape from the cranium forwards and backwards, and ramify over the whole of the body so as to connect it with the organ of the soul: the nerves of the internal senses, [moral and intellectual faculties], on the other hand, have no object beyond the cranium, and are therefore found rolled up on themselves and forming the masses of the brain." (Archiv. fur Physiol., 1802, band vi., s. 406.)

the convolutions of the anterior and middle lobes with those of the posterior. Beneath the Corpus Callosum, we find the most extensive of all the longitudinal commissures, the *Fornix*. This is connected in front with the Thalami Optici, the Corpora Mammillaria, the Tuber Cinereum, &c., and behind, it spreads its fibres over the Hippocampi (major and minor), which are nothing else than peculiar convolutions that project into the posterior and descending cornua of the lateral ventricles. The fourth longitudinal commissure is the *Tænia semicircularis*, which forms part of the same system of fibres with the former, connecting the corpus mammillare and thalamus opticus of each side with the middle lobe of the cerebral hemisphere. If, as Dr Todd has remarked,* we could take away the corpus callosum, the grey matter of the internal convolution, and the ventricular prominences of the optic thalami, then all these commissures would fall together and would become united in the same series of longitudinal fibres. Experiment does not throw any light upon the particular functions of the Corpus Callosum and other Commissures, since they can scarcely be divided without severe general injury. It would appear however that the partial or entire absence of these parts, reducing the Cerebrum (in this respect at least) to the level of that of the Marsupial Quadruped or of the Bird, is by no means an unfrequent cause of deficient intellectual power.†

568. The weight of the entire Encephalon in the adult Male usually ranges between 40 and 60 oz., the average being about 50 oz.; and in the Female from 36 to 50 oz., the average being about 45 oz. The maximum of the healthy brain seems to be about 64 oz., and the minimum about 31 oz. But in cases of Idiocy, the amount is sometimes un[illegible]

* "Anatomy of the Brain, Spinal Cord," &c., p. 234.

† The following case of deficient commissures, recorded by Mr Paget ("Medico-Chirurg. Transactions," vol. xxix.), is of much interest. The middle portion of the Fornix and the whole of the Septum Lucidum, were absent; and in place of the Corpus Callosum there was only a thin fasciculated layer of fibrous matter, 1½ inch in length, of which none of the fibres extended to all the parts of the brain into which the fibres of the Corpus callosum can be traced. The Middle commissure was very large; and the lateral parts of the Fornix, with the rest of the Brain, was quite healthy. The patient was a young girl, who died of pericarditis. She had displayed nothing very remarkable in her mental condition, during her life, beyond a peculiar *want of forethought* and *power of [illegible] the probable event of things*. Her memory was good; and she possessed as [illegible] knowledge as is commonly acquired by persons in her rank of life. She was of good character, trustworthy, and fully competent to all the duties of her station, though somewhat heedless; her temper was good, and disposition cheerful. The mental defects in most of the few other cases of which the details have been recorded, seem to have been of the same order; and this is exactly what might have been anticipated, since the deficiency of these parts takes away that, which is most characteristic of the Cerebrum [illegible] and of the higher Mammalia; *their* intellectual operations being peculiarly [illegible] by that *application of past experience to the prediction of the future*, which [illegible] one of the highest efforts of intelligence. Another case has been since put on record by Mr Mitchell Henry (Op. cit., vol. xxxi.), in which the anterior portion of the Corpus Callosum was deficient, together with the middle and anterior portions of the Fornix and the whole of the Septum Lucidum. There was in this case also a marked intellectual deficiency, but apparently of a different character from that which showed itself in the preceding case; for instead of vivacity and habitual rapidity of action, there was [illegible] proportionate degree of slowness in action, amounting almost to stupidity. The difference in the two cases, however, is perhaps to be set down rather to the account of [illegible] temperament; since in both of them there seems to have been a deficiency in the power of carrying on a continuous train of thought.

below this; as low a weight as 20 ounces having been recorded. —It appears, from the recent investigations of M. Bourgery, that the relative sizes of the different component elements of the Human Encephalon are somewhat as follows. Dividing the whole into 204 parts, the weight of the Cerebrum will be represented by about 170 of those parts, that of the Cerebellum by 21, and that of the Medulla Oblongata with the Optic Thalami and Corpora Striata at 13. The weight of the Spinal Cord would be, on the same scale, 7 parts. Hence the Cerebral Hemispheres of Man include an amount of nervous matter, which is *four* times that of all the rest of the Cranio-Spinal mass, more than *eight* times that of the Cerebellum, *thirteen* times that of the Medulla Oblongata, &c., and *twenty-four* times that of the Spinal Cord.—The average weight of the whole Encephalon, in proportion to that of the body, in Man, taking the average of a great number of observations, is about 1 to 36. This is a much larger proportion than that which obtains in most other animals; thus the average of Mammalia is stated by M. Leuret to be 1 to 186, that of Birds 1 to 212, that of Reptiles 1 to 1321, and that of Fishes 1 to 5668. It is interesting to remark, in reference to these estimates, that the Encephalic prolongation of the Medulla Oblongata in Man (being about one-sixteenth of the weight of the whole Encephalon) is *alone* more than twice as heavy in proportion to his body, as the *entire* Encephalon of Reptiles, and ten times as heavy as that of Fish.—But there are some animals in which the weight of the Encephalon bears a higher proportion to that of the body than it does in Man; thus in the Blue-headed Tit, the proportion is as 1 to 12, in the Goldfinch as 1 to 24, and in the Field-Mouse as 1 to 31. It does not hence follow, however, that the *Cerebrum* is larger in proportion; in fact, it is probably not nearly so large; for in Birds and Rodent Mammals, the Sensory Ganglia form a very considerable proportion of the entire Encephalon. The importance of distinguishing between the several parts of this mass, which are marked-out as distinct, alike by their structure and connections, and by the history of their development, has not been by any means sufficiently attended to.

569. The Encephalon altogether receives a supply of Blood, the amount of which is very remarkable, when its comparative bulk is considered, the proportion which goes to it being, according to the estimate of Haller, as much as one-fifth of the whole mass. The manner in which this blood is conveyed to the brain, and the conditions of its distribution, offer some peculiarities worthy of notice. The two Vertebral and two Carotid arteries, by which the blood enters the cavity of the cranium, have a more free communication by anastomosis, than any similar set of arteries elsewhere; and this is obviously destined to prevent an obstruction in one trunk from interrupting the supply of blood to the parts through which its branches are chiefly distributed,—the cessation of the circulation through the nervous matter being immediately productive of suspension of its functional activity (PRINC. OF GEN. PHYS.)—Not only must there be a sufficient supply of blood, but it must make a regulated pressure on the walls of the vessels. Now the Encephalon is differently circumstanced from other vascular organs, in being enclosed within an unyielding bony case (§ 281); and we find a special provision for equalizing the bulk of the contents of this cavity, and for counterbalancing the results of differences in the functional activity of the brain and in its

supply of blood, in the existence of a fluid which is found beneath the arachnoid, both on the surface of the brain and spinal cord, and in the ventricles of the former. The amount of this 'cerebro-spinal fluid' seems to average about two ounces; but in cases of atrophy of the brain, as much as twelve ounces of fluid may sometimes be obtained from the cranio-spinal cavity; whilst in all instances in which the bulk of the brain has undergone an increase, whether from the production of additional nervous tissue, or from undue turgescence of the vessels, there is either a diminution or a total absence of this fluid. It appears from the experiments of Magendie (to whom our knowledge of its importance is chiefly due), that its withdrawal in living animals causes great disturbance of the cerebral functions, probably by allowing undue distension of the blood-vessels; it is, however, capable of being very rapidly regenerated; and its reproduction restores the nervous centres to their natural state.—As the 'cerebro-spinal fluid' can readily find its way from the sub-arachnoid spaces of the *cranial* cavity into those of the *spinal*, and as it is no less readily absorbed than reproduced, it evidently serves as an equalizer of the amount of pressure within the cranial cavity; admitting the distension or contraction of the vessels to take place, within certain limits, without any considerable change in the degree of compression to which the nervous matter is subjected. That this uniformity is of the greatest importance to the functional exercise of the brain, is evident from a few well-known facts. If an aperture be made in the skull, and the protruding portion of the brain be subjected to pressure, the immediate suspension of the activity of the whole organ is the result; in this manner, a state resembling profound sleep can be induced in a moment, the normal activity being renewed as momentarily, so soon as the pressure is withdrawn. This phenomenon has often been observed in the Human subject, in cases in which a portion of the cranial envelope has been lost by disease or injury. The various symptoms of Cerebral disturbance which are due to a state of general Plethora, are evidently owing to an *excess* of pressure within the vessels; but an undue diminution of pressure is no less injurious, as appears from the disturbance in the Cerebral functions which results from the very opposite cause, namely a depression of the power of the heart, or a deficiency of blood in the vessels.—It is of peculiar importance to bear in mind the disturbance of the Cerebral functions occasioned by variations of internal *pressure*, when we are endeavouring to draw inferences from the phenomena presented by disease.

570. We shall now proceed with our Physiological inquiry into the functions of the Cerebrum; and shall appeal, as before, to Human and Comparative Anatomy, to Experiment, and to Pathology, for our chief data.—The anatomical relations of the Cerebrum to the other Encephalic centres, clearly demonstrate that it is not one of the essential or fundamental portions of the Nervous system; but a superadded organ, receiving all its impulses to action from the parts below, and operating upon the body at large through them. And its great bulk, joined to its position at the summit of the whole apparatus,—the vesicular substance of its convolutions affording a termination to the fibres in connection with it, and not being for the most part only traversed by them, as is the case with that of all the lower centres,—clearly mark it out as the highest in its functional relations, and as ministering, so far as any

material instrument may do, to the exercise of those psychical powers, which, in Man, exhibit so remarkable a predominance over the mere animal instincts. This conclusion is fully borne-out, when we extend our inquiries from Human to Comparative Anatomy; for with some apparent exceptions, which there would probably be no great difficulty in explaining if we were in possession of all the requisite data, there is a very close correspondence between the relative development of the *Cerebrum* in the several tribes of Vertebrata,* and the degree of *Intelligence* they respectively possess,—using the latter term as a comprehensive expression of that series of mental actions, which consists in the *intentional* adaptation of means to ends, based on definite *ideas* as to the nature of both. It is not always easy to say, in the case of the lower animals, what parts of their actions are to be attributed to automatic impulses (*i.e.* to be considered as Instinctive), and what should be regarded as the results of Intelligence. The character of Intelligent actions, however, as compared with Instinctive (§ 459), is usually shown (1) in the *variety* of means which are adopted to compass the same ends, and this not merely by different individuals and by successive generations, but by the same individual at different times; (2) by the improvement in the mode of accomplishing the object, which results from the intelligent use of experience, and from the greater command of means which is progressively attained; and (3) by the conformity of the means to altered circumstances, so that the character of adaptiveness is still maintained, however widely the new conditions may depart from those which must be considered as natural to the species.

571. The difference between actions which proceed from the Intellectual faculties prompted by the instinctive propensities, and those of a purely Instinctive character, is well seen in comparing Birds with Insects. The Instinctive tendencies of the two classes are of nearly the same kind; and the usual arts which both exhibit in the construction of their habitations, in procuring their food, and in escaping from danger, must be regarded as intuitive, on account of the uniformity with which they are practised by different individuals of the same species, and the perfection with which they are exercised on the very first occasion. But in the adaptation of their operations to peculiar circumstances, Birds display a variety and fertility of resource, far surpassing that which is manifested by Insects; and it can scarcely be doubted by those who attentively observe their habits, that in such adaptations they are often guided by real Intelligence. This must be the case, for example, when they make trial of several means, and select that one which best answers the purpose; or when they make an obvious improvement from year to year in the comforts of their dwelling; or when they are influenced in the choice of a situation, by peculiar circumstances, which in a state of nature can scarcely be supposed to affect them. The complete domesticability of many Birds is in itself a proof of their possessing a certain degree of intelligence; but this alone does not indicate the possession of more than a very low amount of it, since many of the most domesticable animals are of the humblest intellectual capacity, and seem to become attached to Man, principally as the source on which they depend for the supply of

* See "Princ. of Comp. Phys.," §§ 662, *et seq.*

their animal wants. But there are certain tribes of Birds, especially the Parrots and their allies, which possess an extraordinary degree of *educability*, and which manifest a power of performing simple acts of *reasoning*, that are quite comparable with those of a child when first learning to talk.

572. This development of the Intelligence under the influence of Man, and in accordance with *his* habits, rather than with the original habits of their species, is yet more remarkable in the case of those Mammals whose instincts lead them to attach themselves peculiarly to him, and whose powers of reasoning are called-forth in adapting themselves to the new circumstances in which they are thus placed. The actions of a Dog, a Horse, or an Elephant are evidently the result, in many instances, of a complex train of reasoning, differing in no essential respect from that which Man would perform in similar circumstances; so that the epithet 'half-reasoning,' commonly applied to these animals, does not express the whole truth; for their mental processes are of the same *kind* with those of Man, and differ more in the *degree* of comprehensiveness of their data and conclusiveness of their inferences, than they do in their essential character. We have no evidence, however, that any of the lower animals have a voluntary power of *directing* their mental operations, at all similar to that which Man possesses; these operations, indeed, seem to be of very much the same character as those which we perform in connected dreams, different trains of thought commencing as they are suggested, and proceeding according to the usual laws, until some other disturb them. Although it is customary to regard the Dog and the Elephant as the most intelligent among the lower animals, it is not certain that we do so with justice; for it is very possible that we are misled by that peculiar attachment to Man, which in them must be termed an instinct, and which enters as a motive into a large proportion of their actions; and that, if we were more acquainted with the psychical characters of the higher Quadrumana, we should find in *them* a greater degree of mental capability than we now attribute to them. One thing is certain, that the higher the degree of Intelligence which we find characteristic of a particular race, the greater is the degree of variation which we meet-with in the characters of individuals; thus everybody knows that there are stupid Dogs and clever Dogs, ill-tempered Dogs and good tempered Dogs,—as there are stupid Men and clever Men, ill tempered Men and good-tempered Men. But no one could distinguish between a stupid Bee and a clever Bee, or between a good-tempered Wasp and an ill tempered Wasp, simply because all *their* actions are prompted by an unvarying Instinct.

573. In estimating the relative development of the Cerebrum in different tribes of Animals, and in comparing this with their relative Intelligence, it must be borne in mind that the *size* of the organ does not, considered alone, afford a means of accurate judgment as to its *power*. For the quantity of vesicular matter which it contains, affords the only fair criterion of the latter; and of this we must judge, not merely by the superficial area, but by the number and depth of the convolutions, and by the thickness of the cortical layer. Again, there are many reasons why it is not fair to estimate the relative development of the Cerebrum by the proportion which it bears to the whole bulk of the animal; and, on the whole, the most accurate basis of comparison would probably be

afforded by the relation between the bulk of the Cerebrum and the diameter of the Spinal Cord. In making any such comparison, however, the Thalami Optici, Corpora Striata, and Corpora Quadrigemina should be excluded from the estimate, for reasons now sufficiently apparent; and the bulk of the Cerebrum *proper* should be alone determined, either by weight, or by the displacement of liquid.—But the Cerebrum varies in different classes and orders of Vertebrata, not merely in proportional size, but also in the relative development of its anterior, middle, and posterior lobes. This is a point of very great importance, in determining the value to be assigned to the organological system of Gall and Spurzheim and their followers. The Cerebrum of the Oviparous Vertebrata is *not* a miniature representative of that of Man, as a whole, but only of his *anterior* lobes; as is sufficiently obvious from an examination of its connections with other parts, and from the absence of any other commissural connections between its two hemispheres, than those which are afforded by the Sensory Ganglia. It is in the Implacental Mammals, that we find the first rudiment of the *middle* lobes of the Cerebrum, and of the proper inter-cerebral commissure, the Corpus Callosum; and even in the Rodents this is but very imperfectly developed. As we ascend the Mammalian series, we find the Cerebrum becoming more and more elongated posteriorly, by the development of the middle lobes, and the inter-cerebral commissure becomes more complete; but we must ascend as high as the Carnivora, before we find the least vestige of the *posterior* lobes; and the rudiment which these possess, and which is enlarged in the Quadrumana, only attains its full development in Man, in whom alone the posterior lobes extend so far backwards as completely to cover-in the Cerebellum.*—The attention which has yet been given to this department of inquiry, has not hitherto done more than confirm the statement already made, with regard to the general correspondence between the development of the Cerebrum and the manifestations of Intelligence; very decided evidence of which is furnished by the great enlargement of the Cerebrum, and the corresponding alteration in the form of the Cranium, which present themselves in those races of Dogs most distinguished for their educability, when compared with those whose condition approximates most closely to what was probably their original state of wildness.

574. This general inference drawn from Comparative Anatomy, is borne-out by observation of the Human species. When the Cerebrum is fully developed, it offers innumerable diversities of form and size among various individuals, and there are as many diversities of character.

* It has been asserted by the followers of Gall, that the development of the Cerebrum from behind forwards, as above described, is rather apparent than real, the whole organ being in fact pushed backwards by the excessive development of the anterior lobe. But the anatomical distinction between the anterior and middle lobes is sufficiently obvious externally, and that of the middle and posterior lobes is also clearly marked-out by the development of the posterior cornua of the lateral ventricles, and the situation of the hippocampus major. Hence the facts above stated do not admit of any such interpretation and they are fully borne out by the history of the Embryonic development of the Cerebrum in Man, which precisely follows the above plan.—It is not here denied that the anterior lobe of the Human Cerebrum is remarkable for its great extension *forwards* but still, the difference between the Cerebrum of Man and that of the lower Mammalia consists much rather in the proportional development of the posterior lobes, than in that of the anterior

It may be doubted if two individuals were ever exactly alike in this respect. That a Cerebrum which is greatly under the average size, is incapable of performing its proper functions, and that the possessor of it must necessarily be more or less idiotic, there can be no reasonable doubt. On the other hand, that a large well-developed Cerebrum is found to exist in persons, who have made themselves conspicuous in the world in virtue of their intellectual achievements, may be stated as a proposition of equal generality. In these opposite cases, we witness most distinctly the antagonism between the Instinctive and Voluntary powers. Those unfortunate beings in whom the Cerebrum is but little developed, are guided almost solely by their instinctive tendencies, which frequently manifest themselves with a degree of strength that would not have been supposed to exist; and occasionally new instincts present themselves, of which the Human being is ordinarily regarded as destitute.* On the other hand, those who have obtained most influence over the *understandings* of others, have always been large brained persons, of strong intellectual and volitional powers, whose emotional tendencies have been subordinated to the reason and will, and who have devoted their whole energy to the particular objects of their pursuit.—It is very different, however, with those who are actuated by what is ordinarily termed *genius*, and whose influence is rather upon the *feelings* and *intuitions*, than upon the understandings, of others. Such persons are often very deficient in the power of even comprehending the ordinary affairs of life; and still more commonly, they show an extreme want of judgment in the management of them, being under the immediate influence of their passions and emotions, which they do not sufficiently endeavour to control by their intelligent will. The life of a 'genius,' whether his bent be towards poetry, music, painting, or pursuits of a more material character, is seldom one which can be held up for imitation. In such persons, the *general* power of the mind being low, the Cerebrum is not usually found of any great size.—The *mere* comparative size of the Cerebrum, however, affords no accurate measure of the amount of mental power; for we not unfrequently meet with men possessing large and well-formed heads, whose psychical capability is not greater than that of others, the dimensions of whose crania have the same general proportion, but are of much less absolute size. Large brains, with deficient activity, are commonly found in persons of what has been termed the *phlegmatic* temperament, in whom the general processes of life seem in a torpid and indolent state; whilst small brains and great activity, betoken what are known as the *sanguine* and *nervous* temperaments.

575. Having now inquired into the evidence of the *general* functions of the Cerebrum, which may be derived from examination of its Comparative development, we proceed to our other sources of information, Experiment and Pathological phenomena. From neither of these, however, is much positive information to be derived.—All the results of

* A remarkable instance of this was published some years since. A perfectly idiotic girl, in Paris, having been seduced by some miscreant, was delivered of a child without assistance; and it was found that she had *gnawed* the umbilical cord in two, in the same manner as is practised by the lower animals. It is scarcely to be supposed that she had any idea of the *object* of this separation.

experiments concur to establish the fact, that no irritation, either of the vesicular or of the fibrous substance, produces either sensation or motion These results are borne-out by pathological observations in Man; for it has been frequently remarked, when it has been necessary to separate protruded portions of the Brain from the remainder, that this has given-rise to no sensation, even in cases in which the mind has been perfectly clear at the time, nor has any convulsive action been produced. The results of partial mutilations are usually, in the first instance, a general disturbance of the Cerebral functions; which subsequently, however, more or less quickly subsides, leaving but little apparent affection of the animal functions, except muscular weakness. The whole of *one* Hemisphere has been removed in this way, without any evident consequence, save a temporary feebleness of the limbs on the opposite side of the body, and what was supposed to be a deficiency of sight through the opposite eye. The former was speedily recovered from, and the animal performed all its movements as well as before; the latter, however, was permanent, but the pupil remained active. When the upper part only of both Cerebral Hemispheres was removed by Hertwig, the animal was reduced, for fifteen days, to nearly the same condition with the one from which they had been altogether withdrawn; but afterwards, sensibility evidently returned, and the muscular power did not appear to be much diminished.

The effects of the entire removal of the Cerebral Hemispheres have been already stated (§ 529). So far as any inferences can be safely drawn from them, these fully bear out the conclusion that the Cerebrum is the organ of Intelligence; since the animals which have suffered this mutilation appear to be constantly plunged in a profound sleep, from which no irritation ever seems able to arouse them into full activity, although they give manifestations of consciousness. It would be wrong hence to infer, however, as some have done, that such would be the natural condition of an animal without a Cerebrum; since it is obvious that much of the disturbance of the sensorial powers which is occasioned by this operation, is fairly attributable to the laying-open of the cranial cavity, to the disturbance of the normal vascular pressure, and to the injury necessarily done to the parts which are left, by their severance from the Cerebrum. Hence the persistence of consciousness, after the entire removal of the Cerebrum,—which proves that the Cerebrum is *not* its seat, or at least *not its exclusive* seat,—is a far more important fact than the positive destruction of psychical power which is consequent upon the operation. So far as they can be trusted, however, the results of such mutilations bear-out the views already put-forth, as to the superadded and non-essential character of the Cerebrum; and justify us in applying to the higher animals the inferences to which we should be led by the contemplation of those forms of the nervous system in which no Cerebrum exists. There is nothing, therefore, to oppose the conclusion, that whilst *sensations* may be felt, and sensori-motor actions excited, independently of the Cerebrum,* the presence of this organ is essential to the formation of *ideas* or notions respecting the objects of sense, and to the performance of those psychical

* It is worthy of remark, that M. Flourens, who in the first instance maintained that sensation is altogether destroyed by the removal of the Cerebrum, has substituted, in the Second Edition of his Researches, the word *perception* for *sensation*; apparently implying exactly what is maintained above.

operations for which ideas furnish at once the material and the stimulus to activity.

576. The information afforded by Pathological phenomena is equally far from being definite. Many instances are on record, in which extensive disease has occurred in *one* Hemisphere, so as almost entirely to destroy it, without either any obvious injury to the mental powers, or any interruption of the influence of the mind upon the body. But there is no case on record, of any such severe lesion of *both* hemispheres, in which morbid phenomena were not evident during life. It is true that in Chronic Hydrocephalus, a very remarkable alteration in the condition of the Brain sometimes presents itself, which might *à priori* have been supposed destructive to its power of activity; the ventricles being so enormously distended with fluid, that the cerebral matter has seemed but a thin lamina, spread over the interior of the enlarged cranium. But there is no proof that absolute destruction of any part was thus occasioned; and it would seem that the very gradual nature of the change, gives the structure time for accommodating itself to it. This, in fact, is to be noticed in all diseases of the Encephalon. A *sudden* lesion, that may be so trifling as to escape observation, unless this be very carefully conducted, will occasion very severe symptoms; whilst a chronic disease may gradually extend itself, without any external manifestation. It will usually be found that sudden paralysis, of which the seat is in the Brain, results from some slight effusion of blood in the substance or in the neighbourhood of the Corpora Striata; whilst, if it follow disorder of long standing, a much greater amount of lesion commonly presents itself. In either case, the paralysis occurs in the opposite side of the *body*, as we should expect from the decussation of the Pyramids; but it may occur either on the same, or on the opposite side of the *face*, the cause of which is not very apparent. If convulsions accompany the paralysis, we may infer that the Corpora Quadrigemina, or the parts below, are involved in the injury; and in this case it is usually found that the convulsions are on the paralysed side of the body,—the effect of the lesion, both of the Cerebrum and of the Corpora Quadrigemina, being propagated to the opposite side, by the decussation of the Pyramids. Where, as not unfrequently happens, there is paralysis of one side, accompanying convulsions on the other, it is commonly the result of a lesion affecting the base of the Brain and Medulla Oblongata, on the side on which the convulsions take place; here the effect of the lesion has to *cross* from the Brain, whilst its influence on the Medulla Oblongata is shown on the same side. Many anomalies present themselves, however, which are by no means capable of explanation, in the present state of our knowledge.—The disturbance of the Cerebral functions, occasioned by those changes in its texture which are commonly included under the general term Inflammation, presents a marked diversity of character, according to the part it affects. Thus it is well known that the Delirium of excitement is usually a symptom of inflammation of the cortical substance, or of the membranes of the Hemispheres. This is exactly what might be anticipated from the foregoing premises, since this condition is a perversion of the ordinary mental operations, which are dependent upon the instrumentality of the vesicular matter; and it is evidently impossible for the membranes to be affected with inflammation, without the nutrition of this substance being

impaired, since it derives all its vessels directly from them. On the other hand, inflammation of the fibrous portion of the Cerebrum is usually attended rather with a state of torpor, than with excitement; and with diminished power of the will over the muscles. It is stated by Foville, that in acute cases of Insanity, he has usually found the cortical substance intensely red, but without adhesion to the membranes; whilst in chronic cases, it is indurated and adherent: but where the insanity has been complicated with Paralysis, he has usually found the medullary portion indurated and congested.

577. The general result of such investigations is, that the Cerebrum is the instrument of all those *psychical* operations, which we include under the general term *Intellectual*, whilst it also affords, in part at least, the instrumental conditions of *Emotional* states; and that all those muscular movements which result from *voluntary* determinations, or which are directly consequent upon *emotional* excitement, have their origin in its vesicular substance, though the motor impulse is immediately furnished by the Cranio-Spinal apparatus, upon which the Cerebrum plays (§ 550). It does not hence follow, however, that the Cerebrum has such a direct relation to the Mind, that the consciousness is immediately and necessarily affected by changes taking-place in its own substance; and, however startling the proposition may at first sight appear, that the organ of the intellectual operations is not itself endowed with consciousness, a careful consideration of the relations of the Cerebrum to the Sensory Ganglia will tend to show that there is no *à priori* absurdity in such a notion. For if the connection of the vesicular matter of the Cerebral Hemispheres with the Sensorial Centres, be anatomically the same as that which exists between these centres and the Retina or any other peripheral expansion of vesicular matter in an organ of sense, which we have seen that it is (§ 566),—and if the same kind of change may be excited in the Sensorial Centres by an impression from each source, which has been shown to be a matter of common occurrence (§ 549),—it can scarcely be deemed unlikely that the Sensorial Centres should be the seat of consciousness, not merely for the impressions transmitted to them by the nerves of the external senses, but also for the impressions brought to them by the 'nerves of the internal senses,' as we may designate (after Reil) the radiating fibres of the Cerebral Hemispheres (§ 566). And there is on the other hand an *à priori* improbability that there should be *two* seats of consciousness, so far removed from one another as the Sensory Ganglia and the vesicular surface of the Hemispheres (for to their medullary substance no such attribute can be assigned with the least probability), an idea which is quite at variance with that very simple and familiar class of phenomena, which consists in the *recollection of sensations* (§ 591). For the remembered sensation is so completely the reproduction of the original, that we can hardly suppose the seat of the two to be different; yet the act of recollection is clearly Intellectual, and therefore Cerebral; consequently, if we admit that the Sensory Ganglia are the seat of the original sensation, we can scarcely but admit that they are also the seat of that which is reproduced by a Cerebral act,—a view which is fully confirmed by the occurrence of automatic movements as consequences of such recal (§ 549). But further, we shall hereafter find evidence to the same effect, in our experience of the occasional evolution of results, such

as ordinarily proceed from intellectual action, without any consciousness on our own parts of the steps whereby these are attained (§§ 652–654).

578. Without presuming, then, to affirm positively what cannot be proved, it may be stated as a probable inference from the Physiological facts already referred-to, and from the Psychological evidence hereafter to be adduced, that the Sensory Ganglia constitute the seat of consciousness, not merely for impressions on the Organs of Sense, but also for changes in the cortical substance of the Cerebrum; so that, until the latter have reacted downwards upon the Sensorium, we have no consciousness either of the formation of ideas, or of any intellectual process of which these may be the subjects.—Ideas, Emotions, Intellectual operations, &c. have of late been frequently designated as 'states of consciousness;' and this psychological description of them is in full harmony with the physiological account here given of the material conditions under which they respectively occur. For as a Sensation is a state of consciousness excited through the instrumentality of the Sensorium, by a certain change (*e.g.*) in the condition of the Retina, it is not difficult to understand how a change in the condition of the Cerebrum may excite, through the same instrumentality, that state of consciousness which may be termed Ideational,* or that another change may produce the Emotional consciousness, another the Intuitional consciousness, another the Logical consciousness. And although it may be thought at first sight to be a departure from the simplicity of Nature, to suppose that the Cerebrum should require another organ to give us a consciousness of its operations, yet we have the knowledge that the Eye does not give us visual consciousness, nor the Ear auditory consciousness, unless they be connected with the Sensory Ganglia; and in the end (the Author feels a strong assurance) it will be found much simpler to accept the doctrine of a common centre for *sensational* and for what may be distinguished as *mental* consciousness, than to regard the two centres as distinct.†—We shall now proceed with a brief analysis of the Mental phenomena, of which the Sensory Ganglia and the Cerebrum afford the material instruments; looking at these, however, rather from their *physiological* than from their *psychological* side.

6. *Of the Mind, and its Operations.*

579. *Correlation of Physiological and Psychical Action.*—It is universally admitted that, notwithstanding all the diversities of Human character and Mental action, there are certain fundamental *uniformities* which may be traced throughout the whole of this series; and it is on

* The Author ventures to use this term, the meaning of which requires no explanation, on the authority of Mr. James Mill, who remarks,—"As we say Sensation, we might also say Ideation; it would be a very useful word, and there is no objection to it, except the pedantic habit of decrying a new term. Sensation is the general name for one part of our constitution [or rather, for one state of our consciousness], Ideation for another." ("Analysis of the Human Mind," vol. i. p. 42.)—If the use of the substantive Ideation be admitted, there can be no reasonable objection to the adjective *ideational*.

† It may serve to give additional confidence in the views above propounded, if the Author mentions that he was led by them to *predict* the psychological phenomena referred-to at the end of § 577, of which he was not at the time aware as facts, but of which he afterwards became assured by the analysis of his own consciousness, and by the communicated experience of others to whom he stated the question.

the basis afforded by these, that the Science of Psychology is erected, to which may be applied, with a mere alteration of form, the definition elsewhere given of Physiology (PRINC. OF GEN. PHYS., p. 1). "The object of the science of *Psychology* is to bring together, in a systematic form, the phenomena which normally present themselves during the existence of *thinking minds;* and to classify and compare these in such a manner, as to deduce from them those general Laws or Principles which express the conditions of their occurrence, and to determine the causes to which they are attributable." As our present object, however, is not so much to investigate the operations of the Mind itself, as to consider their relations to those of the bodily Organism, we shall here enter into the examination of the nature and laws of psychical phenomena, only so far as may be requisite for the elucidation of that mutual action and reaction, which is continually taking place between these two parts of our nature. To the prevalent neglect of this department of study, may be traced many of the fallacies discernible in the arguments adduced on each side, in the oft-repeated controversies between the advocates of the *Materialist* and the *Spiritualist* hypotheses;—controversies in themselves almost as absurd as that mortal contest which (fable tells us) was once carried-on by two knights respecting the material of a shield which they saw from opposite sides, the one maintaining it to be made of gold, the other of silver, and each proving to be in the right as regarded the half seen by himself. Now the moral of this fable, as regards our present enquiry, is, that as the entire shield was really made-up of a gold-half and a silver-half *which joined each other midway*, so the Mind and the Brain, notwithstanding those differences in *properties* which place them in different philosophical categories, are so intimately blended in their *actions*, that more valuable information is to be gained by seeking for it at the points of contact, than can be obtained by the prosecution of those older methods of research, in which Mind has been studied by Metaphysicians altogether without reference to its material instruments, whilst the Brain has been dissected by Anatomists and analyzed by Chemists, as if they expected to map-out the course of Thought, or to weigh or measure the intensity of Emotion.*

580. Although few (if any) Philosophers would be disposed to question that the Cerebrum is the instrument of our higher psychical powers, the

* This inquiry has been started more than once, but has not until recently been systematically prosecuted. "There is one view of the connection between Mind and Matter," says Prof. Dugald Stewart, "which is perfectly agreeable to the just rules of philosophy. The object of this is, to ascertain the laws which regulate their union, without attempting to explain in what manner they are united. Lord Bacon was, I believe, the first who gave a distinct idea of this kind of speculation, and I do not know that much progress has yet been made in it." Considering his own province, however, to be purely Metaphysical, the eminent Professor just quoted gave no further attention to the subject thus adverted-to; and those who have more recently taken it up, having been Physiologists and Physicians, rather than professed Psychologists, have been looked-upon by the latter as opponents rather than as allies. It is much to be desired that a systematic study should be made, by those whose mental training and habits of scientific research qualify them for the task, of that wide and almost unexplored domain, which comprehends the whole range, not only of what may be termed *Mental Physiology*, but also of *Mental Pathology*, and, in addition, the *Comparative Psychology* of the lower Animals, and the *History of Development* of the Human Mind, from the earliest manifestation of its powers

ideas which are entertained of the nature of this instrumentality have been seldom clearly or consistently defined. Some, who have attended exclusively to the close relationship which indubitably exists between corporeal and mental states, have thought that *all* the operations of the Mind are but manifestations or expressions of material changes in the Brain; that thus Man is but a *thinking machine*, his conduct being entirely determined by his original constitution, modified by subsequent conditions over which he has no control, and his fancied power of self-direction being altogether a delusion; and hence that notions of *duty* or *responsibility* have no real foundation, Man's character being formed *for* him, and not *by* him, and his mode of action in each individual case being simply the consequence of the reaction of his Cerebrum upon the impressions which called it into play. On this creed, what is commonly termed Criminality is but one form of Insanity, and ought to be treated as such; Insanity itself is nothing else than a disordered action of the Brain; and the highest elevation of Man's *psychical* nature is to be attained by due attention to all the conditions which favour his *physical* development.* —Now this honestly-expressed *Materialist* doctrine recognises certain great facts, on which the unprejudiced and observant Physiologist can scarcely entertain a doubt, notwithstanding that their validity may be denied by those who have had comparatively little opportunity of studying them, or who have so made up their minds to a foregone conclusion, as to be ready to admit nothing which is not in accordance with it. The whole series of phenomena which so plainly mark the influence of the Body on the Mind, of *physical* upon *psychical* states, —the obvious dependence of the normal activity of the Mind upon the healthful nutrition of the Brain, and upon its due supply of oxygenated blood,—the extraordinary influence of local affections of the Cerebrum upon the normal succession of Intellectual operations, as is especially seen in the strange disturbances or 'dislocations' of the memory consequent upon blows on the head,—the large share which certain states of bodily disorder on the part of parents, or conditions tending to induce defective nutrition during the periods of infancy and childhood, have been proved to possess in the induction of Idiocy and

* For the latest and most thorough-going expression of this doctrine, see the "Letters on the Laws of Man's Nature and Development," by Henry G. Atkinson and Harriet Martineau. A few extracts will suffice to show the bearings of this system [illegible] "Instinct, passion, thought, &c. are effects of organized substances." "All [illegible] material causes." "In material conditions I find the origin of all religions, all philosophies, all opinions, all virtues, and 'spiritual conditions and influences,' in the same manner that I find the origin of all diseases and of all insanities in material conditions and causes." "I am what I am; a creature of necessity. I claim neither merit nor demerit." "I feel that I am as completely the result of my nature, and impelled to do what I do, as the needle to point to the north, or the puppet to move according as the string is pulled." "I cannot alter my will, or be other than what I am, and cannot deserve either reward or punishment." It seems to the Author, that every system of Philosophy which regards the succession of Mental Phenomena as determined *solely* by the ordinary laws of Causation, and which rejects the *self-determining* power of the Will (or, which is the same thing, regards the Will as only another expression for the *preponderance of motives*), virtually leads to the same result. On this account, he cannot admit that Mr. John Mill's 'Logic of the Moral Sciences' (Book vi. of his "System of Logic"),—masterly as it must be, as an exposition of the method of investigating *that part* of our psychical nature which *can* be brought within the domain of Law,—is applicable to the Human Mind as a *whole*.

Cretinism,—the complete perversion of all the mental powers and moral feelings, amounting to a temporary insanity, which is produced by Intoxicating agents,—these and numerous other phenomena might be cited in support of the Materialist doctrine; and must be accounted-for by any one who undertakes the solution of this mystery.

581. But these phenomena are not to be looked-at, to the exclusion of the facts of our own internal consciousness. In reducing the Thinking Man to the level of "a puppet that moves according as its strings are pulled," the Materialist Philosopher places himself in complete opposition to the undoubting conviction which almost every one feels, who does not trouble himself by speculating upon the matter, that he really possesses *a self-determining power*, which can rise above all the promptings of external suggestion, and can, to a certain extent, mould external circumstances to its own requirements, instead of being completely subjugated by them. We can scarcely desire a better proof that our possession of this power is a reality and not a self-delusion, than that which is afforded by the comparison of the normal condition of the mind, with that in which the directing power of the Will is in abeyance. This last condition is seen in certain states of Somnambulism, both natural and artificial (§§ 693 695), in the 'Biologized' state (§ 672), and in some other abnormal conditions; the subjects of which may really be considered (so long as those conditions are allowed to last) as mere thinking automata, puppets pulled by directing-strings; their whole course of thought and of action being determined by suggestions conveyed from without, and their own Will having no power to modify or direct this, owing to the temporary suspension of its influence.—To whatever extent, then, we may be ready to admit the dependence of our mental operations upon the organization and functional activity of our Nervous System, we cannot but feel that there is *something beyond and above* all this, to which, in the fully-developed and self-regulating mind, that activity is subordinated; whilst, in rudely trampling on the noblest conceptions of our nature as mere delusions, the Materialist hypothesis is so thoroughly repugnant to the almost intuitive convictions which we draw from the simplest application of our Intelligence to our own Moral Sense, that those who have really experienced these, are made to *feel* its essential fallacies with a certainty that renders logical proof quite unnecessary.

582. Let us turn now to the opposite doctrine held by the *Spiritualists*, in regard to the nature and source of mental phenomena; and consider this in its Physiological relations. To them the Mind appears in the light of a separate immaterial existence, mysteriously connected, indeed, with a bodily instrument, but not dependent upon this in any other way for the conditions of its operation, than as deriving its knowledge of external things through its agency, and as making use of it to execute its determinations, so far as these relate to material objects. On this hypothesis, the operations of the Mind itself, having no relation whatever to those of Matter, are never themselves affected by conditions of the corporeal organism, whose irregularities or defects of activity only pervert or obscure the outward manifestations of the Mind, just as the light of the brightest lamp may be dimmed or distorted by passing through a bad medium; and, further, as the Mind is thus independent

of its material tenement, and of the circumstances in which they may chance to be placed, but is endowed with a complete power of self-government, it is responsible for all its own actions, which must be judged-of by certain fixed standards. Now this doctrine fully recognizes all that is ignored in the preceding; but, on the other hand, it ignores all that *it* recognized and served to account-for; and is not less opposed to facts of most familiar experience. For in placing the Mind outside of the body (so to speak), and in denying that the action of the Mind itself is ever disordered by corporeal conditions, it puts us in the dilemma of either rejecting the plainest evidence, or of admitting that, after all, we know nothing whatever about the Mind itself, all that we *do* know, being that lower part of our mental nature which operates on the body, and is in its turn affected through it.—Those who most fully and consistently carry-out this doctrine, are ready to maintain that even in the state of Intoxication there is no truly mental perversion; and that, in spite of appearances, the *mind* of the Lunatic (*divinæ particula auræ*) is perfectly sound, its bodily instrument being alone disordered. But it cannot be overlooked, that in the delirious ravings of Intoxication or of Fever, or in the conversation and actions of the Lunatic, we have precisely the same evidence of *mental* operation, that we have of the sayings and doings of the same individuals in a state of sanity; and ample testimony to this effect is borne by those, who have observed their own mental state during the access of these conditions, and who have described the alteration which takes place in the course of their thoughts, when as yet neither the sensorial nor the motor apparatus was in the least perturbed.* Nothing, we think, can be more plain to the unprejudiced observer, than that the introduction of Intoxicating agents into the circulating system really perverts the action of the mind, disordering the usual sequence of phenomena most purely psychical, and occasioning new and strange results which are altogether at variance with those of its normal action. And when once the reality of the influence of physical conditions upon purely-mental states is forced upon the Physiologist, he can scarcely refrain from attributing to it a very wide range of action; and thus he is led to the conviction, that however true it may be, that there is something in our mental constitution beyond and above any agency which can be attributed to Matter, the operations of the Mind are in a great degree determined (in our present state of being) by the material conditions with which they are so intimately associated.

583. The whole theory and practice of Education, indeed, involves the distinct recognition of external influences, as having a most important share in the formation of the character; whilst it is the object of every enlightened Educator to foster the development, and to promote the right exercise, of that power by which each individual becomes the director of his own conduct, the arbiter of his own destinies. It may be considered as a legitimate deduction from experience, that until this self-directing power has been acquired, the character *is* the resultant of original constitution, and of the circumstances in which the individual

* See especially the work of M. Moreau, "Du Hachisch et de l'Aliénation Mentale," of which a critical analysis will be found in the "Brit. and For. Med. Rev.," vol. xxii, p. 217; also the well known "Confessions of an English Opium Eater."

is placed; and that so long as the circumstances are unfavourable to the development of the self-directing power, and to the operation of those higher tendencies which should furnish the best motives to its exercise, so long the character of the individual *is* formed *for* him and not *by* him. The real *self-formation* commences with his consciousness of the possession of that power which enables him to determine his own course of thought and action; a power which is exercised by the Will, in virtue of its domination over what may be designated as the *automatic* operation of the Mind. A being entirely governed by the lower passions and instincts, whose higher moral sense has been repressed from its earliest dawn by the degrading influence of the conditions in which he is placed, who has never learned to exercise any kind of self-restraint (or, if he has learned it, has only been trained to use it for the lowest purposes), who has never heard of a God, of Immortality, or of the worth of his Soul,—such a being, one of those heathen outcasts of whom all our great towns are unhappily but too productive, can surely be no more morally responsible for his actions, than the lunatic who has lost whatever self-control he once possessed, and whose moral sense has been altogether perverted by bodily disorder. But let the former be subjected to the training of one of those benevolent individuals who know how to find out "the holy spot in every child's heart;" let patient kindness, continually appealing to the highest motives which the child *can* understand, progressively raise his moral standard, and awaken within him the dormant susceptibilities which enable him to feel that he has a conscience and a duty, that there is a Father who made him, and who watches over his welfare, that there is a hereafter of rewards and punishments, that he has a power within himself of controlling and directing his thoughts and actions;—then, and not till then, in our belief, does he become truly responsible for his actions, either morally or religiously,—then only does he rise from the level of the brute, and begin to show that he is indeed made in the image of his Maker.

584. Thus, then, we see that the Materialist and the Spiritualist doctrines alike recognize, and alike ignore, certain great truths of Human Nature; and the question returns upon us, whether any general expression *can* be framed, which may be in harmony alike with the results of scientific inquiry into the facts of the case, and with those simple teachings of our own consciousness, which must, after all, be recognized as affording the ultimate test of the truth of all Psychological doctrines. Such an expression may be framed, as it appears to the Author, in strict accordance with true philosophy, by withdrawing ourselves entirely from the futile attempt to bring Matter and Mind into the same category, and by fixing our attention exclusively on the relation between *Mind* and *Force*. Although far from thinking that the views here offered express the *whole* truth, or solve *all* the difficulties of the subject, he considers that they express so much *more* than any scheme he has ever heard of, that he ventures to request for them a thoughtful consideration on the part of those who feel, with him, the importance of attaining some definite conceptions on this head.—In the first place it may be remarked, that the whole tendency of Philosophical Investigation at the present day, is to show the utter futility of all the controversies which have been carried on with regard to the relation of *Mind*

and *Matter*. The essential nature of these two entities is such, that no relation of identity *can* exist between them. Matter possesses extension, or occupies space; whilst Mind has no such property. On the other hand, we are cognizant of Matter only through its occupation of space, of which we are informed through our senses; we are cognizant of the existence of Mind by our direct consciousness of feelings and ideas, which are to us the most certain of all realities. But, what is perhaps a more important distinction, the existence of Matter is essentially *passive*; left to itself, it always impresses our consciousness in one and the same mode; and any change in its condition is the consequence of external agency. What have been termed the active states of matter, are really the manifestations of *forces*, of which we can conceive as having an existence independent of matter, and as having no other relation to it than that which consists in their capability of changing its state. Thus Water continues unchanged so long as its temperature remains the same; but the dynamical agency of Heat occasions that mutual repulsion between its particles, which transforms it from a non-elastic liquid into an elastic vapour; and all this heat is given-forth from it again, when the aqueous vapour is transformed back to the liquid state. On the other hand, the existence of Mind is essentially *active*; all its states are states of *change*, and we know nothing whatever of it save by its changes. Sensation, Perception, Idea, Emotion, Reasoning process, &c., in fact every term which expresses a Mental state, is a designation of a phase of mental existence that intervenes between other phases in the *continual succession* of which our idea of Mind consists.

585. But whilst between Matter and Mind it is utterly vain to attempt to establish a relation of identity or analogy, a very close relation may be shown to exist between *Mind* and *Force*. For, in the first place, Force, like Mind, can be conceived-of only as in a state of activity; and our idea of it essentially consists in the succession of different states, under which its manifestations present themselves to our conciousness. But secondly, our consciousness of Force is really as direct, as is that of our own mental states;* our notion of it being based upon our internal sense of the *exertion* which we determinately make to develope one form of Force, which may be taken as the type of all the rest,—that, namely, which produces or which resists motion. When we attempt to lift a weight, or to turn a windlass, or to stop a horse that is running-away, we are directly conscious of a mental exertion, as the immediate and invariable antecedent of the development of motor power through the contraction of our muscles; and the connection of the two is further established by that 'sense of effort' which we intuitively refer to the muscles themselves, arising as it does from their own condition (§ 545); and thus we are led to feel that, in this particular case, Force must be regarded as the direct expression or manifestation of that Mental state which we call Will. The analogy becomes stronger, when we trace it into the relations which these two agencies respectively bear to Matter. For in the phenomena of Voluntary movement, we can scarcely avoid seeing that Mind is one of the dynamical agencies which is capable of acting on Matter; and that, like other such agencies, the mode of its manifestation is affected by the

* This was long since hinted-at by Locke, in the Chapter 'Of Power' in his "Essay on the Human Understanding," Book ii. Chap. xxi.

nature of the material *substratum* through which its influence is exerted. Thus, the Physiologist knows full well, that the immediate operation of the Will is not upon the Muscle but upon the Brain, wherein it excites that active state of Nervous matter, which he designates as the operation of Nerve-force; and that the propagation of this force along the Nerve-trunks is the determining cause of the Muscular contraction, which is the immediate source of the motor power. He knows, too, that this dynamical metamorphosis is effected (like every other analogous change) by the intermediation of a peculiar material *substratum*, which itself undergoes a change of condition; the components both of the Nervous and Muscular substances ceasing to exist under their previous forms, and entering into new combinations.—Thus, then, we have evidence, in what we know of the physiological conditions under which Mind produces Motion, that certain forms of Vital Force constitute the connecting link between the two; and it is difficult to see that the dynamical agency which we term Will is more removed from Nerve-force, on the one hand, than Nerve-force is removed from Motor force on the other. Each, in giving origin to the next, is itself expended, or ceases to exist *as such;* and each bears, in its own intensity, a precise relation to that of its antecedent and its consequent.

586. But we have not only evidence of the excitement of Nerve-force by Mental agency; the converse is equally true, Mental activity being excited by Nerve-force. For this is the case in every act in which our Consciousness is excited through the instrumentality of the Sensorium, whether its condition be affected by impressions made upon Organs of Sense, or by changes in the state of the Cerebrum itself; a certain active condition of the nervous matter of the Sensorium, being (we have every reason to believe) the immediate antecedent of *all* consciousness, whether sensational or ideational. And thus we are led to perceive, that, as the power of the Will can develope Nervous activity, and as Nerve-force can develope Mental activity, there must be a *Correlation* between these two modes of dynamical agency, which is not less intimate and complete than that which exists between Nerve-force on the one hand and Electricity or Heat on the other. (PRINC. OF GEN. PHYS.)

587. This idea of Correlation of Forces will be found completely to harmonize with those phenomena already referred-to, which unmistakeably indicate the influence of physical conditions in the determination of mental states (§ 580); whilst, on the other hand, it explains that relation between Emotional excitement and bodily change, which is manifested in the subsidence of the former, when it has expended itself in the production of the latter (§ 624). And further, it will be found no less applicable to the explanation of all that *automatic* action of the Mind, which consists in the succession of ideas, according to certain 'laws of thought,' without the exercise of any control or direction on the part of the individual to whose consciousness they present themselves, and which manifests itself in the action of those ideas upon the centres of movement. For this succession must be regarded as the exponent of a series of changes taking place in the Cerebrum itself, in respondence to impressions made upon it; whilst the movements which proceed from these must be considered as being no less the results of its 'reflex' or 'ideo-motor' operation, than are the 'consensual' of the reflex action of the Sensory

Ganglia, and the 'excito-motor' of that of the Spinal Cord.* For all Physiological purposes, then, we may consider the nervous matter of the Cerebrum as the *material substratum* through which the metamorphosis of Nerve-force into Mind-force, and of Mind-force into Nerve-force is effected; and as every such metamorphosis involves, like other analogous transformations, a change in the state of the matter through which it is effected, so should we expect that Mental activity would involve the disintegration of the Nervous substance which thus ministers to it. And such appears, from a variety of evidence, to be really the case. (See PRINC. OF GEN. PHYS.)

588. It is obvious that the view here taken does not in the least militate against the idea, that Mind may have an existence altogether independent of the Material body through which it thus manifests itself. All which has been contended for is, that the connection between the Mind and Body is such, that each has, in virtue of its constitution, a determinate relation to the other, in this present state of existence (which is all of which Science can legitimately take cognizance); and that the actions of our Minds, *in so far as they are carried on without any interference from our Will*, may be considered (in the limited sense formerly explained, § 46 *note*) as 'functions of the Cerebrum.'—On the other hand, in the control and direction which the Will has the power of exerting over the course of the thoughts, we have the evidence of a new and independent power, which is entirely opposed in its very nature to all the automatic tendencies, and which, according as it is habitually exerted, tends to render the individual *a free agent*. And, truly, in the existence of this Power, which is capable of dominating over the very highest of those operations that we know-of as connected with corporeal states, we find a better evidence than we gain from the study of any other part of our psychical nature, that *there is* an entity wherein Man's nobility essentially consists, which does not depend for its existence on any play of physical or vital forces, but which makes these subservient to its determinations. It is, in fact, the virtue of the Will, that we are *not* mere thinking automata, mere puppets to be pulled by suggesting-strings, capable of being played-upon by every one who shall have made himself master of our springs of action. It may be freely admitted that such thinking automata *do* exist: for there are many individuals whose Will has never been called into due exercise, and who gradually or almost entirely lose the power of exerting it, becoming the mere creatures of habit and impulse; and there are others in whom (as we shall hereafter see) such states are of occasional occurrence; whilst in others, again, they may be

* The application of the doctrine of 'reflex action' to the Brain, was first fully developed by Dr Laycock of York, in a paper 'On the Reflex Function of the Brain,' read before the Medical Section of the British Association at its meeting in York, Sept., 1844; and afterwards published in the "Brit. and For. Med. Rev.," vol. xix. Not having recognized what appears to the Author the essential distinction, both in their anatomical and physiological relations, between the Sensory Ganglia and the Cerebral or Hemispheric Ganglia, Dr Laycock did not mark-out the distinction between the '*sensori-motor*' or 'consensual' actions, which are the manifestations of the reflex power of the former, and the '*ideo-motor*' actions which depend upon the reflex action of the latter. But in limiting that part of it which is strictly applicable to the Cerebrum, and in applying it to the various states which agree in the common characteristic of the existence of Mental Activity without Volitional control, the Author considers that he is merely giving greater definiteness and a wider application to Dr Laycock's doctrine.

artificially induced. And it is by the study of those states in which the Will is completely in abeyance,—the course of thought being *entirely* determined by the influence of suggestions upon the Mind, whose mode of reaction upon them depends upon its original peculiarities and subsequently-acquired habits,—and by the comparison of such states with that in which an individual, in full possession of all his faculties, and accustomed to the habitual control and direction of his thoughts, determinately applies his judgment to the formation of a decision between various plans of action, involving the appreciation of opposing motives,—that we shall obtain the most satisfactory ideas of what share the Will really takes in the operations of our minds and in the direction of our conduct, and of what must be set down to that Automatic operation of our psychical nature which is correlated to Cerebral action.*

589. This view, moreover, appears to the Author to be capable of legitimate extension, from the constitution of the Human mind, and its relation to our bodily organism, to the notion which we form of the relation of the Mind of the Deity to that Universe, whose phenomena, rightly interpreted, are but a continual revelation of His ceaseless and universal presence. And it seems desirable here to advert to this subject (foreign though it may seem to the proper object of this Treatise), not merely for the sake of showing that the doctrine here propounded is strictly conformable to the highest teachings of religion, but because it seems to afford some guidance towards the solution of difficulties which have perplexed many deep-thinking men, and which have especially tended to keep Science and Religion apart from one another, rendering the physical philosopher either an avowed sceptic or a mere speculative religionist, and inspiring the religionist with a bigotted horror of science.—The conception which each individual forms of the Divine Nature (§ 616), depends in great degree upon his own habits of thought, but there are two extremes, towards one or other of which most of the current notions on this subject may be said to tend, and between which they seem to have oscillated in all periods of the history of Monotheism. These are, *Pantheism*, and *Anthropomorphism*.—Towards the Pantheistic aspect of Deity, we are especially led by the philosophic contemplation of His agency in external Nature, for in proportion as we fix our attention exclusively upon the 'laws' which express the orderly sequence of its phenomena, and upon the 'forces' whose agency we recognize as their immediate causes, do we come to think of the Divine Being as the mere *First Principle* of the Universe, as an all-comprehensive 'Law' to which all other laws are subordinate, as that most general 'Cause' of which all the physical forces are but manifestations. This conception embodies a great truth, and a fundamental error. Its truth is the recognition of the universal and all-controlling agency of the Deity, and of His presence *in* Creation rather than on the outside of it. Its error lies in the absence of any distinct recognition of that *conscious volitional* agency, which is the

* The Author has had the satisfaction of finding that Mr. J. D. Morell, who has acquired for himself a high place among British Psychologists, has considered his views on the Correlation between Mental and Nervous action to be worthy of adoption into his recently published "Elements of Psychology," in which they are connected with a very ingenious doctrine of the Soul, which Mr. M. regards (with many of the older Philosophers) as acting *unconsciously* in the development and conservation of the Body, as well as manifesting itself *consciously* in the phenomena of Mind.

essential attribute of Personality; for without this, the Universe is nothing else than a great self-acting machine, its Laws are but the expression of 'surd necessity,' and all the higher tendencies and aspirations of the Human Soul are but a 'mockery, a delusion, and a snare.'—The Anthropomorphic conception of Deity, on the other hand, arises from the too exclusive contemplation of *our own* nature as the type of the Divine; and although in the highest form in which it may be held, it represents the Deity as a being in whom all the noblest attributes of Man's spiritual essence are expanded to infinity, yet it is practically limited and degraded by the impossibility of *fully* realizing such an existence to our minds; the failings and imperfections incident to our Human nature being attributed to the Divine, in proportion as the low standard of intellectual and moral development in each individual keeps down his idea of possible excellence. Even the lowest form of any such conception, however, embodies (like the Pantheistic) a great truth, though mingled with a large amount of error. It represents the Deity as a *Person*, that is, as possessed of that Intelligent Volition, which we recognize in ourselves as the source of the power we determinately exert, through our bodily organism, upon the world around; and it invests Him also with those Moral attributes, which place him in sympathetic relation with his sentient creatures. But this conception is erroneous, in so far as it represents the Divine Nature as restrained in its operations by any of these limitations which are inherent in the very constitution of Man; and in particular, because it leads those who accept it, to think of the Creator as "a remote and retired mechanician, inspecting from without the engine of creation to see how it performs," and as either leaving it entirely to itself when once it has been brought into full activity, or as only interfering at intervals to change the mode of its operation.

590. Now the truths which these views separately contain, are in perfect harmony with each other; and the very act of bringing them into combination, effects the elimination of the errors with which they were previously associated. For the idea of the universal and all-controlling agency of the Deity, and of His immediate presence throughout Creation, is not found to be in the least degree inconsistent with the idea of His personality, when that idea is detached from the limitations which cling to it in the minds of those, who have not expanded their anthropomorphic conception by the scientific contemplation of Nature. On the contrary, when we have once arrived at that conception of *Force* as an expression of *Will*, which we derive from our own experience of its production, the universal and constantly-sustaining agency of the Deity is recognized in every phenomenon of the external Universe; and we are thus led to feel that in the Material Creation itself, we have the same distinct evidence of His personal existence and ceaseless activity, as we have of the agency of intelligent minds in the creations of artistic Genius, or in the elaborate contrivances of Mechanical skill, or in those written records of Thought which arouse our own psychical nature into kindred activity.

591. *Of Sensational Consciousness.*—The origin of all Mental activity lies in *affections of the Consciousness*, produced by *impressions* made upon some part of our bodily organism that is supplied with afferent nerves, and transmitted through them to the Sensorium; and affections of the consciousness thus directly occasioned by impressions external to it, ar

termed *Sensations*.* —If it were possible for a Human being to come into the world, with a Brain perfectly prepared to be the instrument of psychical operations, but with all the inlets to sensation closed, we have every reason to believe that the Mind would remain dormant, like a seed buried deep in the earth. The attentive study of cases in which there is congenital deficiency of one or more sensations, makes it evident that the Mind is utterly incapable of forming any definite ideas in regard to those properties of objects, of which those particular sensations are adapted to take cognizance. Thus the man who is born blind can form no conception of colour; nor the congenitally deaf, of musical tones. And in those lamentable cases, in which the sense of Touch is the only one through which ideas can be called-forth, the mental operations necessarily remain of the simplest and most limited character, unless the utmost attention be given by a judicious instructor, to the development of the intellectual faculties, and the cultivation of the moral feelings, through that restricted class of ideas which there *is* a possibility of exciting.†—The activity of the Mind, then, is just as much the result of its consciousness of external impressions, by which its faculties are called into play, as the Life of the body is dependent upon the appropriation of nutrient materials, and the constant influence of external forces. But there is this difference between the two cases,—that whilst the Body continually requires *new* materials and a continued action of external agencies, the Mind, when it has been once called into activity, and has become stored with ideas, may remain active, and may develope new relations and combinations amongst these, after the complete closure of the sensorial inlets by which new ideas can be excited *ab externo*. Such, in fact, is what is continually going on in the state of Dreaming; but examples yet more remarkable are furnished in the vivid conceptions which may be formed of a landscape or a picture, from oral description, by those who have once enjoyed sight; or in the composition of music, even such as involves new combinations of sounds, by those who have become deaf, as in the well-known case of Beethoven. The mind thus feeds, as it were, upon the store of ideas which it has laid-up during the activity of its sensory organs; and not only are those impressions which it *consciously* retains, worked-up into a never-ending variety of combinations and successions of ideas, thus continuing to afford new sources of mental activity even to the very end of life, but those impressions of which the mind, though once conscious of them, seems even to itself to have entirely lost the traces, may recur spontaneously and influence its trains of thought, at periods long subsequent to their reception. Hence we seem justified in affirming that some change must be effected in the condition of the Nervous Centres, by every impression of which we become conscious, whereby that impression is organically perpetuated, in such a manner as to allow of its presenting itself anew to the cognizance of the mind at any future time when it may be excited from a passive to an

* Some Physiologists, it is true, have spoken of a *sensation without consciousness;* but it seems very desirable, for the sake of clearness and accuracy, to limit the application of the word to the *mental* change, especially since the term 'impression' serves to designate that change in the state of the Nervous system, which is its immediate antecedent.

† Of the extent to which this *may* be accomplished, the well-known case of Laura Bridgeman affords a most remarkable exemplification.

active condition. Examples of this kind are occasionally furnished by the delirium of fever or phrenitis; for although it commonly happens that *ideas* are thus recalled, in the first instance, rather than sensations, yet there are some very striking cases, in which the sensations have been of such a kind that no definite idea could well have been attached to them by the individual. A very extraordinary case of this kind has been recorded,* in which a woman, during the delirium of fever, continually repeated sentences in languages unknown to those around her, which were found to be Latin, Greek, and Hebrew, chiefly of the Rabbinical dialect. Of these she stated herself, on her recovery, to be perfectly ignorant; but on tracing her former history, it was ascertained that in early life she had lived as servant with a clergyman, who had been accustomed to walk up and down his passage, repeating or reading aloud sentences in these languages, which she must have retained in her memory unconsciously to herself.—Of the nature of the change by which sensory impressions are thus registered, it seems in vain to speculate; there can be little question, however, that it is in some way dependent upon the nutrition of the Encephalon, since we see that alterations in that function have a marked effect upon the Memory. Thus, in the case just cited, we can scarcely doubt that some alteration either in the circulation of the blood, or in the quality of the fluid, was the cause of changes, which, operating in the substance of the Sensorium, reproduced the former sensations; just as a disturbance of the circulation in the retina occasions the sensation of flashes of light or other visual phenomena (§ 5[illegible]).

592. The acuteness with which particular Sensations are felt, is influenced in a remarkable degree by the *Attention* they receive from the mind. If the mind be entirely inactive, as in profound sleep, no sensation whatever is produced by ordinary impressions; and the same is the case when the attention is so completely concentrated upon some object of thought or contemplation, that impressions altogether unconnected with it fail to make any impression on the sensational consciousness. On the other hand, when the attention is from any cause strongly directed towards them, impressions that are very feeble in themselves produce sensations of even painful acuteness; thus every one knows how much a slight itching of some part of the surface may be magnified by the direction of the thoughts to it, whilst, as soon as they are forced by some stronger impression into another channel, the irritation is no longer felt; so, too, it must be within the experience of most persons, how vividly sounds are perceived when they break-in upon the stillness of the night, being increased in strength, not only by the contrast, but by absorbing the whole attention. An interesting experiment is mentioned by Müller, which shows how completely the mind may be unconscious of impressions communicated to it by one organ of sense, when occupied, even without a distinct effort of the will, by those received through another. If we look at a sheet of white paper through two differently-coloured glasses at the same time (one being placed before each eye), the resulting sensation is seldom that of a mixture of the colours: if the experiment be tried with blue and yellow glasses, for example, we do not see the paper of a uniform green; but the blue is predominant at one moment, and the

* Coleridge's "Biographia Literaria," vol. i. p. 112.

yellow at another; or blue nebulous spots may present themselves on a yellow field, or yellow spots on a blue field. We perceive from this experiment, that the Attention may not only be directed to the impressions made on either retina, to the complete exclusion of those of the other, but it may be directed to those made on particular spots of either. This may be noticed, again, in the process by which we make ourselves acquainted with a landscape or a picture; if our Attention be directed to the whole field of vision at once, we see nothing distinctly; and it is only by abstracting ourselves from the contemplation of the greater part of it, and by directing our attention to smaller portions in succession, that we can obtain a definite conception of the details. The same is the case in regard to auditory impressions, and here the power of Attention, in causing one sensation or series of sensations to predominate over others which are really more intense, is often most remarkably manifested. When we are listening to a piece of music played by a large orchestra, for example, we may either attend to the combined effect of all the instruments, or we may single-out any one part in the harmony, and follow this through all its mazes; and a person with a practised ear (as it is commonly but erroneously termed, it being not the *ear* but the *mind* that is practised,) can even distinguish the sound of the weakest instrument in the whole band, and can follow its strain through the entire performance. This attention to a single element can only be given, however, by withdrawing the mind from the perception of the remainder; and a musician who thus listens, will have very little idea of the rest of the harmonic parts, or of the general effect. In fact, when the mind is thus directed, by a strong effort of the Will, into a particular channel, it may be almost considered as unconscious *quoad* any other impressions; and in those curious states (§§ 672, 694) in which it can be entirely governed by external suggestion, its attention may be so completely concentrated upon some other objects, that even the most painful impressions do not affect the consciousness.

593. The effects of Attention are manifested, not only in regard to the sensations which are excited by external impressions, but also in respect to those which originate within the system. Every one is aware how difficult it is to keep the body perfectly quiescent,* especially when there is a particular motive for doing so, and when the attention is strongly directed to the object. This is experienced even whilst a photogenic likeness is being taken, when the position is chosen by the individual, and a support is adapted to assist him in retaining it; and it is still more strongly felt by the performers in the 'tableaux vivans,' who cannot keep up the effort for more than three or four minutes. Now it is well known that, when the attention is strongly directed to an entirely different object (when we are listening, for example, to an eloquent sermon or an interesting lecture), the body may remain perfectly motionless for a much longer period; the uneasy sensations, which would otherwise have induced the individual to change his position, not being perceived: but no sooner is the discourse ended, than a simultaneous movement of the whole audience takes place, every one then becoming conscious of some discomfort, which he seeks to relieve. This is the case also in regard to

* Of course the movements of respiration and winking are left out of the question.

the respiratory sensation; for it may generally be observed that the usual reflex movements do not suffice for the perfect aeration of the blood, and that a more prolonged inspiration, prompted by an uneasy feeling, takes place at intervals; but under such circumstances as those just alluded to, this feeling is not experienced until the attention ceases to be engaged by a more powerful stimulus, and then it manifests itself in the deep inspirations, which accompany, in almost every individual, the general movement of the body.

594. It is a general rule, with regard to all sensations, that their intensity is much affected by *Habit;* being greatly diminished by frequent and continual repetition. This is not the case, however, with regard to those sensations to which the attention is peculiarly directed, for these lose none of their acuteness by frequent repetition: on the contrary, they become much more readily cognizable by the mind (§ 738). We have a good example of both facts, in the effects of sounds upon sleeping persons (§§ 686, 687). The general law, then, seems to be, that Sensations, not *attended to*, are blunted by frequent repetition; and this may perhaps be connected with certain other general facts, which lie under the observation of every one.—It is well known that the vividness of sensations depends rather on the degree of *change* which they produce in the system, than on the *absolute amount* of the impressing force; and this is the case with regard alike to the special and to the ordinary sensations. Thus our sensations of heat and cold are entirely governed by the previous condition of the parts affected; as is shown by the well known experiment of putting one hand into hot water, the other into cold, and then transferring both into tepid water, which will seem cool to one hand, and warm to the other. Every one knows, too, how much more we are affected by a warm day at the commencement of summer, than by an equally hot day later in the season. The same is the case in regard to light and sound, smell and taste. A person going out of a totally dark room into one moderately bright, is for the time painfully impressed by the light, but soon becomes habituated to it; whilst another, who enters it from a room brilliantly illuminated, will consider it dark and gloomy. Those who are constantly exposed to very loud noises become almost unconscious of them, and are even undisturbed by them in sleep; and the medical student well knows, that even the effluvia of the dissecting-room are not perceived, when the organ of smell is habituated to them; although an intermission of sufficient length would, in either instance, occasion a renewal of the first unpleasant feelings, when the individual is again subjected to the impression.—Thus there seems reason to believe that sensorial changes of frequent occurrence, produce a modification in the nutrition of the Sensorium itself, which grows to them, as it were, just as other Nervous Centres may be considered as growing to the mode in which they are habitually exercised (§ 515). For not only would the production of such a modification be quite in accordance with the general phenomena of Nutrition,* but we can scarcely

* We have a remarkable exemplification of this, in the *tolerance* which may be gradually established in the system for various toxic agents, especially for such as particularly affect the Nervous substance, such as Opium or Alcohol. It seems impossible to explain this tolerance on any other hypothesis, than that of the alteration of the nutrition of the tissue by repeated doses, so that no further change can be produced by the quantity originally taken.

otherwise explain the progressive formation of that connection between sensorial changes and motor actions, which gives rise to the 'secondarily automatic' movements (§ 540).—Hence it seems reasonable to attribute that diminution in the force of Sensations which is the consequence of their habitual recurrence, to the want of such a *change* in the condition of the Sensorium as is needful to produce an impression on the consciousness, the effects which they at first induced being no longer experienced in the same degree, when the structure of the part has accommodated itself to them.

595. Feelings of Pain or Pleasure are connected with particular sensations, which cannot (for the most part at least) be explained upon any other principle, than that of the necessary association of these feelings, by an original law of our nature, with the sensations in question. As a general rule, it may be stated, that the *violent* excitement of *any* sensation is disagreeable, even when the same sensation in a moderate degree may be a source of extreme pleasure. This is the case alike with those impressions, which are communicated through the organs of sight, hearing, smell, and taste, as with those that are received through the nerves of common sensation; and there can be no doubt that the final cause, or purpose, of the association of painful feelings with such violent excitement, is to stimulate the individual to remove himself from what would be injurious in its effects upon the system. Thus, the pain resulting from violent pressure on the cutaneous surface, or from the proximity of a heated body, gives warning of the danger of injury, and excites mental operations destined to remove the part from the influence of the injurious cause: and this is shown by the fact, that loss of sensibility is frequently the indirect occasion of severe lesions,—the individual not receiving the customary intimation that an injurious process is taking place.* Instances have occurred, in which violent inflammation of the membrane lining the air-passages, has resulted from the effects of ammoniacal vapours introduced into them during a state of syncope,—the patient not receiving that notice of the irritation, which, in an active condition of his nervous system, would have prevented him from inhaling the noxious agent.

* The following case, recorded in the "Journal of a Naturalist," affords a remarkable instance of this general fact. The correctness of the statement having been called in question, it was fully confirmed by Mr. Richard Smith, the late senior Surgeon of the Bristol Infirmary, under whose care the sufferer had been. "A travelling man, one winter's evening, laid himself down upon the platform of a lime-kiln, placing his feet, probably numbed with cold, upon the heap of stones, newly put on to burn through the night. Sleep overcame him in this situation; the fire gradually rising and increasing, until it ignited the stones upon which his feet were placed. Lulled by the warmth, the man slept on, the fire increased until it burned one foot (which probably was extended over a vent-hole, and part of the leg above the ankle entirely off, consuming that part so effectually, that a cinder-like fragment was alone remaining,—and still the wretch slept on! and in this state was found by the kiln-man in the morning. Insensible to any pain, and ignorant of his misfortune, he attempted to rise and pursue his journey, but missing his shoe, requested to have it found; and when he was raised, putting his burnt limb to the ground to support his body, the extremity of his leg-bone, the tibia, crumbled into fragments, having been calcined into lime. Still he expressed no sense of pain, and probably experienced none; from the gradual operation of the fire, and his own torpidity during the hours his foot was consuming. This poor drover survived his misfortunes in the hospital about a fortnight, but the fire having extended to other parts of his body, recovery was hopeless."

596. The feelings of Pain or Pleasure, which unaccustomed sensations excite, are often exchanged for each other, when the system is *habituated* to them; this is especially the case in regard to impressions communicated through the organs of Smell and Taste. There are many articles in common use among mankind,—such as tobacco, fermented liquors, &c., the use of which cannot be said to produce a natural enjoyment, since they are at first unpleasant to most persons; and yet they first become tolerable, then agreeable; and at last the want of them is felt as a painful privation, and the stimulus must be applied in an increasing degree in order to produce the usual effect.

597. It is through the medium of Sensation, that we acquire a knowledge of the material world around us, by the psychical operations which its changes excite in ourselves. The various kinds or modes of Sensation excite in us various ideas regarding the properties of matter; and these properties are known to us, only through the changes which they produce in the several organs that constitute the Sensorium (§ 591). But with regard to all kinds of Sensation it is to be remembered, that as the change of which the Mind is informed, is *not* the change at the peripheral extremities of the nerves, but the change communicated to the Sensorium, it hence results, that external agencies can give rise to no kind of sensation, which may not also be produced by internal causes exciting changes in the condition of the nerves in their course, or in the Sensorium itself. This very frequently happens in regard to the senses of sight and hearing; flashes of light being seen, and ringing sounds in the ears being heard, when no external stimulus has produced such impressions. The production of odorous and gustative sensations from internal causes, is perhaps less common; but the sense of nausea is more frequently excited in this manner, than by the direct contact of a nauseating substance with the tongue or fauces. The various phases of common sensibility often originate thus; and the sense of temperature is frequently affected without any corresponding affection of the tactile sensations, a person being sensible of heat or of chilliness in some part of his body, without any real alteration of its temperature. The most common of the internal causes of these *subjective* sensations (as they have been termed, in contradistinction to the *objective*, which result from a real material object), is congestion or inflammation; and it is interesting to remark that this cause, operating through each nerve, produces in the sensorium the changes to which that nerve usually ministers. Thus, congestion in the nerves of common sensation gives rise to feelings of pain or uneasiness; but when occurring in the retina or optic nerve, it produces flashes of light; and in the auditory nerve, it occasions 'a noise in the ears.'—But further, the phenomena of *subjective* sensation often originate in peculiar conditions of the Encephalon itself, and not in the organs of sense or the nervous trunks; thus, in Dreaming, we frequently have very vivid pictures of external objects presented to our minds; and we sometimes distinctly hear voices and musical tones, or have perceptions (though this is less common) of tastes and odours. The phenomena of Spectral Illusions are very nearly connected with those of dreaming; both may be in some degree influenced by external causes, acting upon the organs of sensation, which are misinterpreted (as it were) by the mind, owing to its state of imperfect operation;

but both also may entirely originate in the central organs. There seems to be no difference, in the feelings of the individual, between the sensations thus originating, and those which are produced in the usual manner; for we find that, unless convinced to the contrary by their reason, persons who witness spectral illusions believe as firmly in the reality of the objects that come before their minds, as if the images of those objects were actually formed on their retinæ. This is another proof, if any were wanting, that the organ of sense, with the nerve belonging to it, is but the instrument by which certain changes are produced in the Sensorium; by which changes, and not by the immediate impressions of the objects, our Consciousness is really affected.

598. There is yet another mode, however, in which Subjective sensations may be excited, namely by sensations originating in objective impressions on *other* parts. Thus the irritation of a calculus in the bladder gives-rise to pain at the end of the penis; disease of the hip-joint is often first indicated by pain in the knee; irritation of the ovary will cause pain under the mamma; various disorders of the liver occasion pain under the left scapula; attention is often drawn to diseases of the heart by shooting pains along the arms; stimulation of the nipple, whether in the male or female, gives-rise to peculiar sensations referred to the genital organs; the sudden introduction of ice into the stomach will cause intense pain in the supra-orbital region, and the same pain is frequently occasioned by the presence of acid in the stomach, and may be very quickly relieved by its neutralization with an alkali. It will be seen that in most of these cases, it is impossible to refer the sensations to any direct nervous connection with the parts on which the impressions are made; and they can scarcely be otherwise accounted-for, than by supposing that these impressions produce sensorial changes, which are referred to other parts, in virtue of some *central* track of communication with them, analogous to that through which reflex movements are excited. There are circumstances, indeed, which seem to render it not improbable, that just as the impression brought by the afferent nerves to the central organs, excites a reflex movement by disturbing the polarity of a motor nerve, it may excite a 'reflex sensation' by disturbing the polarity of a sensory nerve. Certain it is that, after the long continuance of some of these reflex sensations, the organs to which they are referred themselves become diseased, although previously quite healthy; thus, pain in the testicles is frequently induced by irritation having its seat in the lower part of the spine, on which if it continue, some morbid affection of the testicle itself is likely to supervene; and Sir B. Brodie* has recorded several cases, in which 'nervous' pains in various parts, apparently of a purely subjective character, have been followed by pain and swelling of the integuments. These phenomena are perhaps due to that habitual direction of the consciousness to the part, which is prompted by the habitual sensation; this condition, as we shall see hereafter (CHAP. XV.), being itself adequate to the production of changes in its ordinary nutritive action.

599. It seems to be by an innate law of our constitution, that these

* "On Local Nervous Affections," 1837.

subjective sensations, whether originating at the central terminations of nerves, or in the course of their trunks, should be referred by the mind to the ordinary situations of their peripheral extremities (§ 474 I.), even though these should not exist, or should be destitute of the power of receiving impressions. Thus after amputations, the patients are for some time affected with sensations (probably excited by irritation at the cut ends of the nerves), which they refer to the removed extremities; the same has been noticed in regard to the eye, as well when it has been completely extirpated, as when its powers have been destroyed by disease. The effects of the Taliacotian operation afford a curiously-illustrative example of this principle; for until the flap of skin from which the new nose is formed, obtains vascular and nervous connections in its new situation, the sensation produced by touching it is referred to the forehead. Another interesting illustration of it may be obtained by the following very simple experiment: if the middle finger of either hand be crossed behind the fore-finger, so that its extremity is on the radial side of the latter, and the ends of the two fingers thus disposed be rolled over a marble, pea, or other round body, a sensation will be produced, which, if uncorrected by reason, would cause the mind to believe in the existence of two distinct bodies; this is due to the impression being made at the same time upon the radial side of the forefinger, and the ulnar side of the middle finger,—two spots which, in the natural position, are at a considerable distance. —Sensations of a purely Subjective nature may excite precisely the same muscular movements, or other changes in the bodily system, as do similar sensations produced by objective realities. Of this we have abundant evidence in the effects of sensations called-up by ideas (§§ 549, 602); the following example, however, is peculiarly valuable, as showing that the sensation still operates in directing movement, even though there be an intellectual consciousness that there is no objective cause for it, and that the movement is consequently inappropriate. A lady nearly connected with the Author, having been frightened in childhood by a black cat, which sprang-up from beneath her pillow just as she was laying her head upon it, was accustomed for many years afterwards, whenever she was at all indisposed, to see a black cat on the ground before her; and although perfectly aware of the spectral character of the appearance, yet she could never avoid lifting her foot as if to step over the cat, when it seemed to be lying in her path.

600. It is remarkable that not merely are Subjective sensations, like all others, rendered more intense by the direction of the attention to them, but they may be actually called into existence by the fixation of the attention on certain parts of the body; and, with yet greater force, by the belief in the existence of objective causes for such sensations. The 'effects of mental attention on bodily organs' have been specially pointed-out by Sir H. Holland;* from whose examples the following may be cited in proof of the foregoing position. "The attention concentrated, for so by an effort of will it may be, on the head or sensorium, gives certain feelings of tension and uneasiness, caused possibly by some change in the circulation of the part; though it may be an effect, how-

* See his valuable Essay on that subject in his "Medical Notes and Reflections," and in his "Chapters on Mental Physiology."

ever difficult to be conceived, on the nervous system itself. Persistence in this effort, which is seldom indeed possible beyond a short time without confusion, produces results of much more complex nature, and scarcely to be defined by any common terms of language." "Stimulated attention will frequently give a local sense of arterial pulsation where not frequently felt, and create or augment those singing noises in the ears, which probably depend on the circulation through the capillary vessels." A similar direction of consciousness to the region of the stomach, "creates in this part a sense of weight, oppression, or other less definite uneasiness; and, when the stomach is full, appears greatly to disturb the due digestion of the food. The state and action of the bowels are much influenced by the same cause." A peculiar sense of weight and restlessness approaching to cramp, is felt in a limb, to which the attention is particularly directed. So, again, if the attention be steadily directed to almost any part of the surface of the body, some feeling of itching, creeping, or tickling will soon be experienced.—The fact that sensations may be *modified* by previous beliefs, which must be within the experience of every one, is remarkably illustrated by the well-known exclamation of Dr. Pearson, "Bless me, how heavy it is," when he first poised upon his finger the globule of potassium produced by the battery of Davy; his preconception of the coincidence between metallic lustre and high specific gravity, causing him to feel *that* as ponderous, which the unerring test of the balance determined to be lighter than water.

601. Of the absolute *production* of Subjective sensations by the conviction of the existence of their objective causes, the two following cases, related by Prof. Bennett,* are very satisfactory examples; the effect of the idea not being limited to the production of the sensations, but extending itself to the consequences which would have followed those sensations if their supposed cause had been real. "A clergyman told me, that some time ago suspicions were entertained in his parish, of a woman who was supposed to have poisoned her newly-born infant. The coffin was exhumed, and the procurator-fiscal, who attended with the medical men to examine the body, declared that he already perceived the odour of decomposition, which made him feel faint, and in consequence he withdrew. But, on opening the coffin, it was found to be empty; and it was afterwards ascertained that no child had been born, and consequently no murder committed."—The second case is yet more remarkable. "A butcher was brought into the shop of Mr. Macfarlan, the druggist, from the market-place opposite, labouring under a terrible accident. The man, on trying to hook-up a heavy piece of meat above his head, slipped, and the sharp hook penetrated his arm, so that he himself was suspended. On being examined, he was pale, almost pulseless, and expressed himself as suffering acute agony. The arm could not be moved without causing excessive pain; and in cutting-off the sleeve, he frequently cried out; yet when the arm was exposed, it was found to be quite uninjured, the hook having only traversed the sleeve of his coat!"—In this and similar cases, the sensation was perfectly *real* to the individual who experienced it; but it originated in a Cerebral (ideational) change, which produced its impression through the nerves

* "The Mesmeric Mania of 1851." Edinburgh, 1851.

of *internal* sensation (§ 566), instead of in an impression upon the nerves of the *external* senses to which it was referred. Of this kind of action we shall see other examples, in the production of sensations by 'suggestion' in the state of artificial Reverie (§ 672). And the excitement of the peculiar sensation of tickling in a 'ticklish' person by any movement that suggests the idea, and of that of creeping or itching by the mention of bed-infesting insects to those who are peculiarly liable to their attacks, are familiar instances of the same fact, which strongly confirms the general doctrines heretofore advanced, respecting the analogy between the peripheral surface of the Cerebrum and the peripheral expansions of the Sensory nerves, as regards their mutual relations to the Sensorium (§ 577).

602. On the same level with the simple feelings of pleasure and pain which are associated with our Sensational consciousness, but distinct from these in the manner in which they affect us, are those general feelings of personal *well-being*, or of its reverse *malaise*, which, whilst so intimately connected with states of the bodily system as to be producible by them alone, are also the rudimentary forms of those higher psychical states which we term Emotions. These feelings, in their lowest stage of development, are purely subjective; the individual being simply conscious of them, and not referring them to any external source. There are many persons who are so keenly susceptible of both, that they pass their whole lives in an alternation between *cheerfulness* and *depression*; the former state being favoured by freedom from anxiety, by the healthful activity of all the organic functions, by a bright sun and a dry bracing atmosphere; whilst the latter is immediately induced by mental disquietude, by a slight disorder of digestion or excretion, or by a dull oppressive day. And a concurrence of favourable conditions may even exalt this *Cœnæsthesis* (or self-feeling) into *exhilaration* or absolute *joy*, whilst the combined influence of those of the opposite kind may produce *gloom* which may be exaggerated almost to *despair*. The condition of 'the spirits' (as these mental affections are commonly designated) most to be desired, however, is that of *tranquil comfort*, for this is far more favourable than the alternation of extremes, to healthful activity and to sustained energy, both of body and of mind. And this may be cherished by cultivating the habit of Volitional self-restraint (§ 462), whereby any tendency to undue exhilaration is moderated, and excessive depression is resisted by a determinate effort not to yield to it. The same states of consciousness may be excited by causes purely Psychical, and although we are then accustomed to designate them as Emotions, yet their nature and their seat are probably the same in the one case as the other. For if, like the Sensations with which they are so closely associated, they are impressed on our consciousness by the instrumentality of the Sensory Ganglia, it is easy to see, on the principles already explained, how they may be called into activity by impressions conveyed thither by the 'nerves of the internal senses,' as well as by those which arrive there through the 'nerves of common sensation' which are distributed through the body. It often happens, moreover, that the impression thus made upon the 'Emotional sensibility' is more persistent than the mental state which gave rise to it; for after some disagreeable occurrence, or the receipt of ill-tidings, we feel an abiding consciousness of discomfort or

distress, although we determinately keep from our mental view the recollection of the unpleasant idea, in order that we may not be disturbed by dwelling too painfully on it. It may often be observed, moreover, that when the passions have been excited in states of Somnambulism, Hypnotism, &c., a disturbed *Cœnæsthesis* is carried-on into the ordinary state, although the 'subject' is altogether unconscious of the nature or causes of the Emotional paroxysm.*—There are few other forms of Emotional sensibility, which are so completely subjective as the foregoing; most of them having reference to some object which is felt to be external to self, and therefore belonging to the next category. But we seem justified in referring to this group, as being nearly allied to the foregoing, though scarcely capable of being grouped together with them, *the sense of enjoyment in activity*, and its converse *the sense of tedium in inactivity* (commonly known as *ennui*); both of which are purely subjective states, and are obviously manifested by the lower animals, chiefly, however, in connection with their *bodily* functions, whilst in Man it is the want of *mental* occupation that is the chief source of Ennui

603. *Perceptive and Intuitional Consciousness.*—Neither the operations of the Intellectual Powers, nor the higher Emotional states, are *immediately* called-forth by the Sensational consciousness; for if we do not advance beyond this, we merely recognize the fact that certain changes have occurred in our own 'subjective' state, and do not refer these changes to any external or 'objective' source. Of such a limitation, we occasionally meet with examples among the phenomena of Dreaming, and in some of the conditions resulting from the use of Anæsthetic agents; for if we fall asleep whilst suffering from bodily pain, we may entirely lose all perception of the cause of that pain as having its seat in our own bodily fabric, and yet remain conscious of a perturbed state of feeling; and when a surgical operation is performed in a state of incomplete Anæsthesia, it is obvious that pain is felt without any distinct consciousness of its source, and the patient may subsequently describe his state as an uneasy dream. Such, it is probable, is the condition of the Infant at the commencement of its psychical life "If," as has been well remarked by Mr. Morell,† "we could by any means transport ourselves into the mind of an infant before the perceptive consciousness is awakened, we should find it in a state of absolute isolation from everything else in the world around it. Whatever objects may be presented to the eye, the ear, or the touch, they are treated simply as subjective feelings, without the mind's possessing any consciousness of them *as objects* at all. To it, the inward world is *everything*, the outward world is *nothing*."—However difficult it may be, under the influence of our life-long experience, to dissociate any sensation of which we are cognizant, from the notion of its external cause—since, the moment the feeling is experienced, and the mind is directed to it, the object from which it arises is immediately suggested,—yet nothing is more certain than that all of which we are ourselves conscious, in any case whatever, is a certain internal or subjective state, a change in our previous consciousness, and that the mental recognition of the object to which that change is due, is dependent upon

* For a remarkable case of this, see the Author's Art. *Sleep*, in the "Cyclop. of Anat. and Phys.," vol. iv p. 693.

† "Philosophy of Religion," p. 7.

a higher mental process, to which the name of *Perception* or *Perceptive Consciousness* is now generally accorded. We may recognize the manifestation of this process in the child, as it advances beyond the first few months of its helplessness. "A sight or a sound," remarks Mr Morell (Op. cit.), "which at first produced simply an involuntary start, now awakens a smile or a look of recognition. The mind is evidently struggling *out of itself;* it begins to throw itself into the objects around, and to live in the world of outward realities." A similar transition, more rapidly effected, may be distinguished in ourselves, during the passage from sleep, or from the insensibility of a swoon, to the state of complete wakefulness; when we are at first conscious only of our own sensations, and gradually come to the knowledge of our condition as it relates to the world around, and of the position and circumstances, new and strange as they may be, in which we find ourselves.

604. Now the *apprehension*, or formation of an elementary notion, of the *outness* or *externality** of the cause of a sensational change, is an operation which the Mind seems necessarily to perform, when it has attained a certain stage of development, instinctively or intuitively making a definite distinction between the *self* and the *not-self*, the *subject* and the *object*. We do not *infer* the existence of objective realities by any act of the Reason; in fact, the strict application of logical processes tends rather to shake than to confirm the belief in the external world; but the qualities of matter are directly and immediately recognized by our minds, and we gradually learn to interpret and combine the impressions they make upon our consciousness, so as to derive from them a more or less definite notion of the object. Some of these notions are so simple, and so constantly excited by certain sensations, that we can scarcely do otherwise than attribute their formation to original and fundamental properties of the mind, called into activity by the sensations in question; thus, the notion of *hardness* seems to connect itself from the first with the sense of absolute resistance, the notion of *direction* with the consciousness of diversity of parts in the visual picture. Such perceptions are said to be *intuitive* or *original*. In other cases, however, the notions are connected with the sensations by habit alone, and it is entirely due to the association which gradually establishes itself between them, that the one calls-up the other. This is certainly the case with regard to those perceptions of the relative distances of *remote* objects, which are based upon our apprehension of their sizes, the distinctness with which they are seen, &c. (§ 764); but with regard to our visual perception of solidity or projection (§ 761), which depends upon an appreciation of the relative distances of the several parts of a *near* object (§ 7[illegible]), it will be shown to be questionable whether this is intuitive, or whether it is *acquired* by the early combination of the visual and tactile sense-perceptions. Certain it is, that during the period of infancy, a very rapid and energetic process of self-education is going on, the *whole mind*, so far as it is yet developed, being concentrated upon its perceptive activity. And the judicious parent or nurse will favour this process, by

* This term is to be understood in the present inquiry, as implying what is external to the *mind*. Viewed in that aspect, the bodily organism stands in the same kind of relation to it, as does the world beyond; and the changes in the former which give rise to sensations, are as much *objective* as are those of the latter.

supplying a sufficient variety of objects on which it may be advantageously exercised.—When once a complete interpretation has thus been attained, of any particular group of sensations, it so immediately occurs to the consciousness whenever those sensations may be renewed, as to have all the directness of an original perception; and thus it is very difficult, at later periods of life, to discriminate the perceptions which are really *intuitive*, from those which have been *acquired* during infancy. It would be wrong to draw inferences on this point from the actions of the lower animals; for in those cases in which the young are dependent from the first on the exertion of their own powers, it is obvious that they have a larger range of intuitive perceptions, than is possessed by those which derive their early sustenance from their parents. Many of them, for example, manifest a guiding appreciation of direction and distance, which Man can only gain by long experience. Thus, a fly-catcher just come out of its shell, may be seen to peck at and capture an insect, with an aim as perfect as if it had been all its life engaged in learning the art. Still more remarkable is the perception that guides the actions of a little fish, the *Chætodon rostratus*, which shoots-out drops of fluid from its prolonged snout, so as to strike insects that happen to be near the surface of the water, thus causing them to fall into it, so as to come within its own reach. Now by the laws of refraction of light, the real place of the Insect in the air will not be that at which it appears to the Fish in the water; but it will be a little below its apparent place, and to this point the aim must be directed. But the difference between the real and the apparent place will not be constant; for the more perpendicularly the rays enter the water, the less will be the variation; and, on the other hand, the more oblique the direction, the greater will be the difference. Now it is impossible to imagine but that, by an intuitive perception, the real place of the Insect is made known to the Fish in every instance, as perfectly as it could be to the most sagacious Human mathematician who might determine it in each case by a process of calculation, or to a clever marksman who had learned it practically by a long experience. The Fish, however, simply *acts upon* such knowledge, prompted by an instinctive impulse to do so; whilst Man, even in the lowest stage of his culture (as when in the condition of the child or the savage), consciously separates his own personality from the object which excites his mental activity, and thus only can he lay the foundation for exercising that higher Intelligence, which supersedes in him the Instinct of the lower animals.

605. The formation of *acquired* perceptions, and their gradual assumption of the immediate character of those which belong to our original constitution (thus deserving the designation of *secondarily-intuitive*), bear a striking analogy to the process by which habitual movements come to be linked-on to the sensations that prompt them, so as at last to be automatically performed, although originally guided by the Will (§ 540). And it can scarcely be regarded as improbable, that, in the one case as in the other, the nervous mechanism *grows-to* particular modes of activity (§ 515), so that successions of action are uniformly excited by particular stimuli, which were not provided-for in its original construction. Such a view harmonizes well with the fact, that such associations, both between sensations and respondent *movements*,

and between sensations and respondent *ideas*, are formed much more readily during the period of childhood and adolescence, than they are after the full measure of development has been attained; and that they are much more durable in the former case than in the latter. For that which has been already pointed-out with regard to the nutrition of other tissues (§ 346), may not unreasonably be applied to the Nervous system; that, when once a certain mode of nutrition has been fully established, it tends to perpetuate itself, provided that it be not altogether unconformable to the original type. Throughout the whole constitution of Man, physical and mental, we witness this capacity of adaptation to a great variety of circumstances, and it seems to be purposely left to Man to educate himself in accordance with those circumstances, so that he gradually *acquires* those modes of action, which in other animals are directly prompted by instinctive or intuitive tendencies. Hence although placed at a disadvantage in comparison with them, during the earlier periods of his life, he is enabled ultimately to attain to a far wider range of perceptive appreciation, than that to which they are limited, there being, in fact, no class of sensory impressions, from which, by habitual attention to them, he may not draw information of a far more precise and varied nature than they seemed at first to be capable of affording.

606. We have seen that, for the production of a Sensation, a *conscious* state of mind is all that is required; whilst, on the other hand, for the exercise of the Perceptive power, a certain degree of *attention* is requisite, or, in other words, the Mind must be *directed towards* the sensation. And thus it happens that, when the mind is either inactive, or is completely engrossed by some other subject of thought, the sensation may neither be perceived nor remembered, notwithstanding that we have evidence derived from the respondent movements of the body, that it has been felt. Thus a person in a state of imperfect sleep may start at a loud sound, or may turn-away from a light shining on his face, being conscious of the sensation and acting automatically upon it, but forming no kind of appreciation of the externality of its source. And, in like manner, a person in a state of profound Abstraction (§ 671) may perform many automatic movements, which cannot (so far as we know) be excited except through the medium of sensation; and yet the exciting sensations are neither perceived by him at the time, nor are they afterwards remembered, so that when he is aroused from his reverie, he may be astonished to find himself in circumstances altogether different from those under which he passed into it. Sometimes, however, the sensorial impression may excite a sort of imperfect perception, which is subsequently remembered and completed. For example, the student who does not hear the repeated strokes of the clock when his mind is entirely given-up to his object of pursuit, may have a sort of vague consciousness of them if his attention be less completely engrossed by his studies, and although the sounds may not suggest at the moment any distinct idea of the passage of time, yet, when he subsequently gives his attention to the sensorial impression, he may remember to have heard the clock strike, and may even be able to retrace the number of strokes.* When

* It is curious that in so retracing a number, we are often assisted by mentally reproducing the succession of strokes, *imagining* their recurrence, until we feel that we have counted-up to the impression that was left upon our sensorium. In the same way, if asked

the Attention is directed, however, to the sonorous impressions (as when we are *listening* for the striking of the clock), or when it is not so closely fixed on any other object as to prevent it from being attracted by the sensations, the sounds are not only recognized as proceeding from an external source, which is a simple act of Perception, but the sensations which we perceive are discriminated from all others of like nature; and it is by this kind of mental intensification of the perceptive change to which they give rise, that the sensations themselves are impressed with so much additional force on our consciousness, as to seem extraordinarily increased in acuteness. Although we are accustomed to see this chiefly in cases where some particular kind of perceptive acuteness has been acquired by *habit*, yet we may learn from certain phenomena of Somnambulism (both spontaneous and artificial) that nothing more is needed, than that concentration of the *whole mind* upon the sensorial indications, which is the natural state of the Infant (§ 694).

607. The attainment of that grade of Mental development which enables us to apprehend the objective reality of external things, seems to give us also certain elementary intuitions in regard to them, which are nearly akin to the *feelings* immediately associated with Sensations (§ 602), but which constitute the germs (so to speak) of higher forms of consciousness. Thus the *Æsthetic* sense of the beautiful, of the sublime, of the harmonious, &c. seems in its most elementary form to connect itself immediately with the perceptions which arise out of the contact of our Minds with external Nature. "All those" says Mr. Morell, "who have shown a remarkable appreciation of form and beauty, date their first impressions from a period lying far behind the existence of definite ideas or verbal instruction. The germs of all their Æsthetic impressions manifested themselves, first of all, as a spontaneous feeling or instinct, which, from the earliest dawn of reason, was awakened by the presentation of the phenomena which correspond objectively with it in the universe." These intuitional feelings exist in very different intensity in different individuals; and it is where they have most strongly manifested themselves at a very early period of life (the sense of harmony, for example, in the infant Mozart), that we can see how fundamental a part of our nature they constitute, although they may be but faintly shadowed-forth in a large part of mankind. They are peculiarly susceptible of development, however, by appropriate culture; under the influence of which they not merely grow-up in the individual, but manifest themselves with increased vigour and more extended range in successive generations of mankind.

608. So, too, there seems to lie in this part of our psychical nature, the germ which, in a higher phase of development, is evolved into the *Moral* Sense. Experience shows, as Mr. Morell justly remarks, "that an instinctive *apprehension* of right and wrong, as attached to certain actions, precedes in the child any distinct *comprehension* of the language by which we convey moral truths. Moreover, the power and the purity of moral feeling not unfrequently exist even to the highest degree, amongst

how many stairs there are in a stair case which we are in the habit of using, we may not be able to name the number, yet, when actually ascending or descending, we are conscious that we have arrived at the top or the bottom, by the completion of that series of sensorial changes which have become habitual to us.

those who never made the question of morals in any way the object of direct thought, and may perchance be unconscious of the treasure they possess in their bosoms." And it is only in so far as the doctrines of Ethical science are based upon these fundamental intuitions of our nature, that they possess a firm hold upon our convictions as necessary truths.—"Closely connected with the Moral are the Religious intuitions of the soul; which are developed, more or less distinctly amongst the earliest of our Human Sentiments, in that form of awe, veneration, and reverence, which is inspired by objects of sublimity, grandeur, vastness, and mystery" (Morell) It is by their appeal to these intuitive feelings of reverence, and to the Moral sentiment of goodness, that religious teachings make their first impression on the understanding, and lay the foundation for those more definite ideas of the Divine Being, towards which, in a higher phase of religious development, we direct our consciousness of dependence, and our desire of self-elevation; and which we invest intellectually with those attributes which represent our highest ideal of Power, Wisdom, and Goodness (§ 616).

609. The Moral and Religious intuitions are closely related to those forms of our *Emotional* sensibility, which, being no longer purely subjective, require as a condition of their existence that they shall relate to an external object. This is pre-eminently the case with all those which are termed 'emotions of sympathy;' thus, the perception of the pain or distress of another instinctively excites (except in individuals of a peculiarly unsympathetic temperament) a corresponding affection in the percipient mind, just as the sight of certain bodily movements (as yawning) tends to call forth the same movements in ourselves, and the opposite state of cheerfulness or mirth has a like tendency to affect those who are brought into contact with it, provided that there be nothing positively antagonistic in their own condition. But further, the perception of enjoyment calls-forth a respondent *gladness;* whilst the perception of suffering tends to excite in ourselves that feeling of sorrow which we term *pity*, and either of these feelings may be experienced, even when we do not ourselves share in the state of elevation or depression which excited them.—More closely connected with the foregoing than is commonly conceived, is that sense of the *humorous*, which attaches itself to certain manifestations of character presented to us in the actions of others that *sympathy with Human nature* in which the former have their source being the foundation of the latter also; and thus it happened that those writers who have the strongest power of exciting our sense of humour, are usually distinguished also by their mastery of the pathetic. To the sense of the humorous, that of the *ludicrous* is obviously related; but this, when excited by operations of the intellect, instead of by external objects, belongs to a different category (§ 619). The same may be said of the sense of *wonder;* which in its simplest form may be connected with our sense-perceptions, but which is more commonly experienced in regard to the ideas which they excite. Another group of Emotional feelings belonging to the same category, is that which may receive the general designation of *Attractions* and *Repulsions*. These are the elementary states of those Emotions which involve a distinct *idea* of the object which attracts or repels, and which then assume the forms of *desires* and *aversions* (§ 619), but it is in this form that they seem to act in the lower

animals and in young children, whose minds are not yet fully developed into the stage of ideational consciousness. The various terms *like* and *dislike*, *partiality* and *distaste*, *love* and *hatred*, which we use to signify the modes in which we ourselves feel affected by external objects, indicate the existence of this elementary form of emotional sensibility in connection with the perceptive consciousness.—There are other emotional states, some of them rising to the intensity of *passions*, which seem to belong to this category; but the examples already cited are sufficient to illustrate the doctrine here contended-for.

610. It is a characteristic peculiarity of all the modes of affection of the consciousness which have been now described, that, being the immediate experiences of the percipient mind, they cannot be expressed in language, or conveyed by any system of purposive signs to other minds; although the spontaneous expressions to which they prompt, may be apprehended by other minds in a corresponding state of activity. "If," says Mr. Morell, "we look along the whole range of our intuitions, we find them all alike *unutterable*. They may, indeed, be intensely *felt*, their inward existence, too, may be manifested by a thousand significant indications; nay, they can create an impulse and a sympathy in others, by the very light they kindle in the features, and the power they infuse into the actions of those who intensely realize them, but they cannot be articulately expressed." It is only when they are evolved into those *representative forms* which are termed *Ideas* (§ 613), that they are capable of being expressed by a language either of *signs* or of *sounds*. And it may be noticed that long before children have attained to any comprehension of these, they intuitively interpret the expressions of Emotion, and are sympathetically affected by them; as seems the case, too, with regard to such of the lower animals as habitually associate with Man, and have acquired that sympathy with his emotional nature, which enables them to recognize its manifestations.

611. The Intuitional consciousness is not solely exercised, however, upon the impressions transmitted to it through the external senses. For it appears to be by a like direct action of the mind upon the products of our higher Psychical operations, which come to the Sensorium through the 'nerves of the internal senses' (§ 577), that we apprehend these as *realities* or *necessary truths*. Thus when, by those Intellectual processes of which the Cerebrum is the instrument, we have evolved the abstract idea that "things which are equal to the same thing, are equal to one another," we feel intuitively compelled to recognize that idea as a fact, and whilst no accumulation of appeals to experience would increase our confidence in its validity, so the assertion that experience ever leads to a contrary result, would only call forth the reply that such experience *must* be fallacious. So, again, all logical reasoning is based upon the assumption of the truth of its methods, the only guarantee for which lies in an appeal to the intuitional consciousness; and the conclusion can only be *certainly* relied on, when (as in Mathematical proof) the basis of the whole is an axiom or necessary truth, and at every step of the argument the most indubitable certainty can be felt as to the correctness of the inference.—And thus, in all departments of human knowledge, the *ultima ratio* is afforded by our Intuitional consciousness; which, within the range of its development, is the most certain and direct of all

our means of apprehending truth; and which is the faculty that seems most to link us to that Divine Intelligence, whose all-comprehensive thought takes-in the Universe, with all its past, present, and future as but a point in its Infinite conception.*

612. *Of Ideational Consciousness.*—In ascending the scale of Psychical activity, we find the operations of the Mind becoming more and more detached from the sensational changes which first excited them. We have seen that in the first or Sensational stage, the consciousness is engrossed with *self*, not being as yet awake to the existence of any external cause for the *subjective* change it experiences; whilst in the second or *Perceptive* stage, in which that *objective* cause is apprehended as something *not-self*, the mind is entirely given up to the contemplation of it, and recognizes its properties as the sources of the various affections it experiences. Some of these affections relate to *knowledge*, whilst others partake more of the nature of *feeling*; but in all of them the percipient mind is brought face to face, as it were, with the object perceived, and the intuitive knowledge which arises from this direct relation has a certainty to which no other kind of knowledge can lay claim. But it is not until the Mind attains a still higher kind of activity, that it forms that distinct *mental representation*, or *Idea*,† of the object, which stands altogether apart from our immediate experience, and assumes the character of an independent intellectual reality. In forming this mental representation, the mind is determined by the nature and intensity of the various affections of its consciousness which have been excited by the object; and as these will depend in part upon its original constitution, and in part upon the mode in which it has been habitually exercised, it follows that the ideas or mental representations of the same object or occurrence, which are formed by different individuals, may be widely discrepant. This, indeed, continually proves to be the case; and we cannot have a better example of the fact, than is afforded by the variety in the modes in which the same landscape shall be depicted by different Artists, each expressing in his peculiar 'manner' the representa-

* On all that relates to the Perceptive and Intuitional Consciousness, see especially Mr. J. D. Morell's "Elements of Psychology," Part i. chap. iv.

† The Author thinks it useless to enter into the enquiry which has been the [illegible] of so many abstruse and laboured Metaphysical discussions, as to whether our [illegible] ideas originate altogether *without*, or altogether *within*, the Mind, or partly [illegible] partly within. It will be sufficient for him to express his own conviction, that [illegible] is the only consistent mode of viewing the subject, and is that at which any [illegible] arrive, who discusses *all* the facts of the case according to the true method of [illegible] reasoning. An idea can no more correctly be designated a 'transformed [illegible]' than a sensation could be designated a transformed impression. The one is [illegible] other is consequent. And just as an electrical or chemical stimulus, [illegible] calls it into contraction, so does the sensational stimulus, acting on the perceptive [illegible] excite an idea of the object which gave occasion to the sensation. On the [illegible] affirm that ideas are either 'innate,' or are in any way produced by the Mind [illegible] without original excitement by sensations *ab extra*, is a position so entirely [illegible] with experience, as not to bear any careful scrutiny. The formation of Ideas, [illegible] considered as the reaction between the External World and the Intelligent Mind [illegible] latter possessing within itself certain properties, which the impressions made [illegible] the former are adapted to call into active exercise. For a [illegible] view of the [illegible] doctrines which have been propounded on this subject, and their bearing on the [illegible] idea" which rests on "the primary harmony between the Soul and the Universe," see Mr. J. D. Morell's "Elements of Psychology," pp. 289, *et seq.*

tion which his Mind has formed of that aspect of Nature which it has contemplated.—The influence of preconceived *notions*, or of the *feelings* by which the mind is habitually possessed, may be continually recognized by the observant, as modifying the ideas which every one forms of what is presented to his observation; and it is by an exaggeration of such influences that those *mis*-representations are made, which in certain forms of Insanity, possess the mind of the subject of them with convictions that, to every one else, are palpably inconsistent with reality (§ 711).—This want of conformity between the *ideal* and the *actual* is peculiarly apt to arise in the minds of those, who live too much in the former and too little in the latter; for in proportion as the mind dwells too exclusively upon its own conceptions, and refrains from bringing these into contact with the realities of every-day life, do aberrations, which would speedily be checked by experience, progressively acquire a preponderating influence, until at last they may acquire the character of settled delusions, and may altogether upset the balance of the intellect.

613. The whole tendency of the ideational activity of the Mind, is thus to separate the representation which it forms from the restraints of outward experience, as completely as possible, so as to make it a distinct and intelligible object of contemplation, which can be placed, at pleasure, either within or beyond the grasp of the consciousness at the moment. Now for the perfection of this *objectifying* process, it is requisite that we should possess some mode of *signifying* our ideas, so that they may at the same time be made clear and distinct to ourselves, and be rendered intelligible to other minds. This may be accomplished by means of *signs* visible to the eye, or transmissible through the touch; or by means of spoken *language*, in which certain combinations of sounds are made to symbolize ideas. Now the nearer the signs employed are to the *natural* expressions of the ideas for which they are to stand, the more readily are they comprehended by those to whom they are addressed;* but their range is necessarily very limited, and every family of Mankind has substituted for them a set of *arbitrary* sounds, which are not only much more perfect in themselves as instruments for the expression of ideas, but are capable of being made to convey (by means of that wonderful apparatus of *articulation* with which Man is provided) an unlimited variety of meanings, with every kind of relation of these which the mind can conceive. In proportion as, by inflexion and combination, a language is capable of readily and precisely embodying the results of the intellectual processes, in that proportion can these results be *objectified* by the individual, and be thus made the basis of further operations, and in the same proportion can they be clearly presented to the minds of others, and be employed by them for the same purpose. Thus whilst the

* The deaf-and-dumb are trained to communicate with each other, not merely by the 'finger language,' by which words are alphabetically spelled, but also by the 'sign language,' by which ideas are conveyed through the much more direct medium of single signs. These signs, though partly conventional, are made to conform as nearly as possible to the *natural* expressions of ideas, and are usually acquired very quickly by the deaf-and-dumb, whose want of other modes of utterance forces into activity a mode of expressing their ideas and emotions, which is unnecessary to those who have the command of language, and is consequently but little exerted by them. Young children, however, who associate much with the deaf-and-dumb, very readily acquire this 'sign language,' and will often prefer the continued use of it to the acquirement of *spoken* language.

structure of the language of any people is to a certain extent a measure of its mental development, it comes to exert a most important influence over the further progress and direction of that development, different languages being in their very nature, adapted for the expression, both of different *classes*, and of different *relations*, of ideas.—Although some have maintained that words which are used to designate external objects are the signs of those objects, and that such words form a class distinct from that of the words which stand as signs of abstract ideas, yet a little consideration will show, that except in the case of *proper names** which are only applicable to individuals, *all* words really express *generalized images* of the objects to which they refer. Thus, if we attempt to define the most familiar object, such as a house, a table, or a basket, by any verbal description, we find it extremely difficult to frame a definition that shall include *all* houses, *all* tables, *all* baskets, notwithstanding that our *idea* of a house, of a table, or of a basket, is sufficiently precise to enable us to say at once with regard to any particular object, whether it *does*, or *does not* fall under one of those categories. Hence they do not appeal directly to the intuitions of other minds, but must be comprehended by translation through *their* ideational consciousness. Thus it is, that as expressions of *feeling*, words are often less potent than tones or gestures, which directly appeal to the emotional sensibility of the percipient. And thus it is, too, that words have no absolute meaning, but can only signify to each individual the ideas which he is prepared by his previous habits of thought to attach to them.† Words, in fact (as Mr. Morell has justly remarked, Op. cit., p. 194), "represent simply a *course of mental action*, in which we grasp the essential elements which distinguish one thing from another, and make those elements spontaneously the ground for a classification of our multifarious experiences. In this way it is, that they serve to construct the more general outlines of human knowledge. Hence the wonderful power which words possess in the whole process of human thought; hence the capacity they attain, after the teachings of experience have paved the way, for expressing the very essence of the things to which they relate; hence, too, their use in forming a broad platform, on which the results of all the lower processes of mind are plainly recorded, and from which we can commence

* To the child first learning the use of language, every noun is originally a proper name, standing as the symbol of the *individual* object with which it learns to associate it; but it is very early led by the familiar experiences of its nursery, to apply such words as chair, table, bed, to *classes* of objects, and thus to appreciate their significance as symbols of generalized or abstract ideas. And when that process has been accomplished in a few instances, the child's intellect soon extends it to others, its chief activity in this state of its development, being directed to the expansion and multiplication of its Ideas.

† Thus every branch of knowledge has its own language, the terms of which, even when identical with words in ordinary use, can only convey their full and peculiar signification to those who have already gained an extensive acquaintance with the department of thought to which they relate. So in rendering from one tongue into another, great difficulty is continually experienced in the choice of words which shall convey in the translation the precise ideas signified in the original, the difficulty being greater in proportion to the diversity between the habits of thought of the two nations respectively. We can scarcely have a more 'pregnant instance' of the obstruction thus created to the transmission of ideas through language, by the peculiarity of scientific terminology in combination with diversity of national habitudes of thought, than is presented in the attempt to bring the abstract refinements of German Metaphysics within the comprehension of a 'common sense' English mind.

those higher forms of activity, which give to Reason its all but infinite range, and all but omnipotent force."

614. There are certain Ideas which seem almost necessarily to spring-up in the Mind, during the course of its own operations; and these, being suggested, not so much by perceptions of external objects, as by observation of what is taking place in the Mind itself, are sometimes distinguished as *intellectual*, in contrast to *sensational* ideas. So universally do these present themselves to thinking minds, so little are they subject to modification by peculiarities of individual character (whether original or acquired), and so unhesitatingly are they recognized as truths when they are judged-of by the Intuitional consciousness, that they take rank as *fundamental axioms* or principles of Human Thought. Such are, the belief in our own *present existence*, or the faith which we repose in the evidence of Consciousness, this idea being necessarily associated with every form and condition of mental activity:—the belief in our *past existence*, and in our *personal identity* so far as our memory extends, which is necessarily connected with the act of Recollection; with this, again, is connected the general idea of Time:—the belief in the *external and independent existence* of the causes of our sensations, which results from the direction of the mind to the Perceptional ideas originating in them; with this is connected the general idea of Space:—the belief in the existence of an *efficient cause* for the changes which we witness around us, which springs from the perception of those changes; whence is derived our idea of Power:—the belief in the *stability of the order of nature*, or in the invariable sequence of similar effects to similar causes, which also springs directly from the perception of external changes, and seems prior to all reasoning upon the results of observation of them (being observed to operate most strongly in those whose experience is most scanty, and in relation to subjects that are perfectly new to them); but which is the foundation of all applications of our own experience or of that of others, to the conduct of our lives, or to the extension of our knowledge: lastly, the belief in *our own free will*, involving the general idea of Voluntary Power; which is in like manner a direct result of our internal perception of those mental changes which are excited by sensations. Hence it is evident that "the only foundation of much of our belief, and the only source of much of our knowledge, is to be found in the constitution of our own minds;" but it must be steadily kept in view, that these fundamental Axioms are nothing else than expressions of the general fact, that the ideas in question are uniformly excited (in all ordinarily-constituted minds at least) by simple Attention to the changes in which they originate.

615. Among those elementary modes of thought which arise out of the constitution of our own minds, we must also rank the ideas of Truth, Beauty, and Right, which intuitively present themselves to our consciousness, in connection with certain objects or occurrences respectively adapted to excite them; the first connecting itself especially with the operations of the Reason, the second with those of the Imagination as directed by the Æsthetic Sense, and the third with the determination of the Will in the regulation of conduct, under the guidance of the Moral Sense.—*Truth* may be defined to be an apprehension of the

relations of things as they actually exist; and the conception of truth, which is originally based upon sensational ideas, comes to be also applied to those which are purely intellectual.—The notion of *Beauty*, the germ of which, as we have seen (§ 607), exists in the Intuitional Consciousness, is one that is very difficult to define; but it seems to consist, when fully developed, in the conformity of an external object to a certain ideal standard, by which conformity a pleasurable feeling is produced. That ideal standard is a work of the Imagination, and is generated (by a kind of automatic process) by the elimination of all those elements which we recognize as inferior, and by the intensification and completion of all those which we regard as excellent. Hence according to the æsthetic judgment which every individual pronounces as to these particulars, will be his ideal of beauty. The notion of beauty extends itself also to the pure conceptions of the Intellect; and thus we may experience the sense of beauty in the recognition of a Truth. We experience the sense of beauty, too, in witnessing the conformity of conduct to a high standard of Moral excellence; which excites in our minds a pleasure of the same order, as that which we derive from the contemplation of a noble work of Art.—The idea of *Right*, also suggested by the Intuitional consciousness, connects itself with voluntary action. We have no feeling of approval or disapproval with respect to actions that are necessarily connected with our physical well-being; but in regard to most of those which are left to our choice, it is impossible to feel indifferent, and the sphere of operation of this principle becomes widened, in proportion as the mind dwells upon the notion of Moral Obligation which arises out of it. Then, too, the idea of Right is brought to attach itself to thoughts, as well as to actions; and this, not merely because the right regulation of the thoughts is perceived to be essential to the right regulation of the conduct, but also because the mind intuitively perceives that whatever we can govern by the Will has also a moral aspect.

616. Closely connected with many of the foregoing, and arising in most minds from some or other of them by the very nature of our psychical constitution, are those ideas which relate to the Being and Attributes of the Deity. There is, in fact, no part of Man's psychical nature, which does not speak to him of the Divine, when it is rightly questioned. The very perception of *finite* existence, whether in time or space, leads to the idea of the Infinite. The perception of *dependent* existence, leads to the idea of the Self-existent. The perception of change in the external world, leads to the idea of an Absolute Power as its source. The perception of the order and constancy underlying all those diversities which the surface of Nature presents, leads to the idea of the Unity of that power. The recognition of Intelligent Will as the source of the power we ourselves exert, leads to the idea of a like Will as operating in the Universe. And our own capacity for reasoning, which we know not to have been obtained by our individual exertions, is a direct testimony to the Intelligence of the Being who implanted it.—So are we led from the very existence of our Moral Feelings, to the conception of the existence of attributes, the same in kind, however exalted in degree, in the Divine Being. The sense of Truth implies its actual existence in a being who is Himself its source and centre; and the longing for a yet higher measure of it, which is experienced in the greatest force by those who have already attained the

truest and widest view, is the testimony of our own souls to the Truth of the Divine Nature. The perception of Right, in like manner, leads us to the Absolute lawgiver who implanted it in our constitution; and, as has been well remarked, "all the appeals of innocence against unrighteous force are appeals to eternal justice, and all the visions of moral purity are glimpses of the infinite excellence." The aspirations of the most exalted moral natures after a yet higher state of Holiness and Purity, can only be satisfied by the contemplation of such perfection as no merely Human being has ever attained; and it is only in the contemplation of the Divine Ideal, that they meet their appropriate object. And the sentiment of Beauty, especially as it rises from the material to the spiritual, passes beyond the noblest creations of art and the most perfect realization of it in the outward life, and soars into the region of the Unseen, where alone the imagination can freely expand itself in the contemplation of such Beauty as no objective representation can embody.—And it is by combining, so far as our capacity will admit, the ideas which we thus derive from reflection upon the facts of our own consciousness, with those which we draw from the contemplation of the Universe around us, that we form the justest conception of the Divine Being, of which our finite minds are capable. We are led to conceive of Him as the Absolute, Unchangeable, Self-Existent,—Infinite in duration,—Illimitable in space,—the highest ideal of Truth, Right, and Beauty,—the All-Powerful source of that agency which we recognize in the phenomena of Nature,—the All-Wise designer of that wondrous plan, whose original perfection is the real source of the uniformity and harmony which we recognize in its operation,—the All-Benevolent contriver of the happiness of His sentient creatures,—the All-Just disposer of events in the Moral world, for the evolution of the ultimate ends for which Man was called into existence. In proportion to the elevation of our own spiritual nature, and the harmonious development of its several tendencies, will be the elevation and harmoniousness of our conception of the Divine; and in proportion, more particularly, as we succeed in raising ourselves towards that ideal of perfection which has been graciously presented to us in the "well-beloved Son of God," are the relations of the Divine Nature to our own *felt* to be more intimate. And it is from the consciousness of our relation to God, as His creatures, as His children, and as independent but responsible fellow-workers with Him in accomplishing His great purposes, that all those Ideas and Sentiments arise, which are designated as Religious, and which constitute that most exalted portion of our nature, of whose continued existence and yet higher elevation we have the fullest assurance, both in the depths of our own Consciousness, and in the promises of Revelation.

617. It has been usually considered by Moralists and Theologians, that *Conscience*, or the *Moral Sense*, is an autocratic faculty, which unmistakeably dictates what is right in each individual case, and which should consequently be unhesitatingly obeyed as the supreme and unerring guide. Now this view of the case is attended with practical difficulties, which make it surprising that it can ever have been entertained. For it must be obvious to every one who carefully considers the matter, that whilst *a notion of right and wrong*, attaching itself to certain actions, is as much a part of the moral nature of every individual, as the feeling

of *pleasure* or *pain* attaching itself to certain states of consciousness is of his sensational nature, yet the determination of *what* is right and *what* is wrong, is a matter in great degree dependent upon education, habits of thought, conventional associations, &c., so that the moral standard of no two men shall be precisely alike, and the moral standards of men brought up under entirely-different circumstances shall be of the most opposite nature.* So, whilst the notion of a God sustaining any direct relation to us, involves the notion of *Duty*, which attaches itself to all actions with which He can be considered as having any concern, the dictates of this sense will vary with the ideas entertained respecting the character and requirements of the Deity; and actions may be sincerely regarded as an acceptable sacrifice by one class of religionists, which are loathed as barbarous and detestable by another. Moreover, in what have been designated as 'cases of conscience,' the most enlightened Moralist may have a difficulty in deciding what is the right course of action, simply because the 'moral sense' finds so much to approve on both sides, that it cannot assign a preponderance to either. And the same difficulty attends the determination of religious Duty, in many peculiar contingencies; each of two or more possible modes of action being recommended by its conformity to the Divine law on certain points, whilst it seems opposed to it on others. Thus, individuals in whose characters the love of *truth* and of *justice* and the *benevolent* affections are the prominent features, and who would shrink with horror from any violation of these principles of action for any selfish purpose whatever, are sorely perplexed when these are brought into collision with each other, a strong motive to tell a falsehood (for example) being presented by the desire to protect a defenceless fellow-creature from unmerited oppression or death.†

618. If, then, neither the Moral sense nor the sense of Religious Duty affords a clear and unvarying rule of action in each individual case, it is evident that the determination of what is *right* and *wrong* must be a matter of *judgment*; the rule of Moral action being based on a comparison of the relative nobility of the motives which impel us to either course, and being decided by the preference which is accorded to one or other.

* Without having recourse to the strange estimates of right and wrong which prevail amongst Savage nations, for an illustration of this position, it may be sufficient to compare the different views *conscientiously* entertained on the question of Slavery by high-minded, estimable, and Christian men and women in different parts of the American Union.

† Thus if a man, who might be urged to conceal a fugitive slave near the Canadian frontier, were to refuse to do so merely on the fear of unpleasant consequences to himself, he would be justly branded with the character of a cold-hearted coward; but if his refusal should proceed from the conviction that the Divine Law requires the preference of truthfulness over every other motive, and that, by concealing the suppliant, he would be forced into a violation of that law, he cannot be blamed even by those who feel that the law of compassion written upon our hearts is at least equally imperative. Similar difficulties beset the upholders of the non-resistance creed, which teaches that love is the all-powerful principle in the moral world, and that it should entirely supersede those impulses of our nature which lead us to oppose force to force, and to resist an unprovoked assault. Here, again, we might readily understand and sympathize with those, who consider that the fear of personal suffering does not warrant our doing grievous injury to another in warding off a threatened attack; but when the question becomes one not of *self*-defence, but of protection to *others* who are helpless dependents upon our succour, and who are bound to us by the closest ties of natural affection, we must feel that the comparative nobility of the latter motive warrants actions which our individual position could scarcely justify.

combination of motives above another.* If it be asked, how are the relative values of these motives to be decided, the answer must be sought in the moral consciousness of Mankind in general, which is found to be more and more accordant in this respect, the more faithfully it is interpreted, the more habitually it is acted-on, and the more the whole intelligence is expanded and enlightened. It is this tendency towards universal agreement, which shows that there is really as good a foundation for Moral science in the psychical nature of Man, as there is for that of Music in the pleasure which he derives from certain combinations and successions of sounds. So, again, the more elevated are the religious ideas of Mankind in regard to the character and will of the Deity, the more do they approach to a general accordance in regard to what constitutes Religious Duty; and the complete coincidence which exists between the dictates of the Christian law and the highest principles of pure Morality, prevents one set of motives from ever coming into antagonism with the other. The *Conscience* of the religious man, indeed, may be said to be the *resultant* of the combination of his Moral sense with the idea of Duty which arises out of his sense of relation to the Deity. With the former are closely associated all those emotions and propensities, which render him considerate of the welfare of his fellow-men, as of his own; and with the notion of duty to God are closely united the desire of His favour, the fear of His displeasure, the aspiration after His perfection, all which act like other motives in deciding the Will. Their relative force on any occasion, as compared with that of the lower propensities and sensual desires, greatly depends on the degree in which they are *habitually* brought to influence the mind; and it is in its power of fixing its contemplation on those higher considerations which ought to be paramount to all others, and of withdrawing it from the lower, that the Will has the chief influence in the direction of the conduct according to the dictates of Virtue.

619. *Of the Emotional Consciousness.*—Although, as we have seen (§§ 602, 609), there are various forms of Emotional Sensibility which are

* This view of the nature of Conscience will be found more fully developed in the "Prospective Review" for November 1845, pp. 587-9. "Every moral judgment," it is well remarked by the reviewer, "is *relative*, and involves a comparison of (at least) two terms. When we praise what *has been* done, it is with the coexistent conception of *something else that might have been* done; and when we resolve on a course as *right*, it is to the exclusion of some other that is *wrong*." This is why we cannot attach any moral character to the actions of animals that are performed under the direction of a blind undiscerning instinct, leaving them no choice between one course and another; nor to those which are executed by human beings, even when possessed of their full intelligence, under the domination of impulses which they have it not in their power to restrain; nor, again, to those performed by individuals whose moral sense has either been never awakened, or has been so completely misdirected by early education, that their standard of right and wrong is altogether opposite to that which the enlightened conscience of mankind agrees in adopting. But, although there are doubtless many cases in which criminal actions are committed under the impulse of passions (such as anger, lust, &c.) which the individual has not at the moment the power to control, and although he must be absolved from moral responsibility *quoad* the immediate motives of those particular actions, yet these motives too frequently derive all their force from the habit of yielding to their promptings in lesser matters, which gradually gives them a dominance, such as the Will (weakened by want of exercise in the habit of self-restraint) is unable to resist. Hence the criminal *action* is to be regarded as but the expression of a long previous course of criminal *thought*, for which, in so far he could have otherwise directed it, the individual may legitimately be held responsible.

directly called into activity by sense-perceptions, yet those Emotional states of Mind, which directly or indirectly determine a great part of our conduct, belong to the level of the Ideational consciousness, being in fact, the result of the attachment of the feelings of pleasure and pain and of other forms of emotional sensibility, to certain classes of ideas. Thus the Cerebrum and the Sensory Ganglia would seem to act jointly in their production; for whilst the Cerebral Hemispheres furnish the *ideational* part of the material, the Sensory Ganglia not only give us the consciousness of their result, but invest that result with the peculiar *feeling* which renders it capable of actively influencing our conduct as a *motive* power. This we see most clearly, when the Emotional state takes the form of a true *desire;* for when this is felt, even as regards the gratification of a bodily appetite, it involves the existence of an idea of *the object* of desire; but it is only when this idea is associated with the contemplation of enjoyment in the act to which it relates, or of discomfort in the abstinence from that act, that it becomes an impelling force towards the performance of it.—All the higher forms of Emotional consciousness may be decomposed (as it seems to the Author) in a similar manner. Thus, Benevolence is the pleasurable contemplation of the happiness or welfare of others; and shows itself alike in the habitual entertainment of the abstract or general idea, and in the direction of the conduct with a view to promote this result in any particular instance on which the benevolent desire may be fixed. So there is a positive pleasure, in some ill-constituted minds, in the contemplation of the unhappiness of others; and this we designate as Malevolence. Again, the Combativeness of Phrenologists is nothing else than the pleasurable idea of setting one's self in antagonism with others; which may manifest itself either physically or psychically, according to the temperament of the individual.* So, Pride (or self-esteem) consists in the pleasurable contemplation of our own superior excellencies; whilst the essence of Vanity (or love of approbation) lies in the pleasurable idea of the applause of others. Again, in Conscientiousness we have the love of right that is the association of pleasure with the idea of right; Veneration may be defined as the pleasurable contemplation of rank or perfections superior to our own; and the source of Ambition, which is in some degree an antagonistic tendency, lies in the pleasurable idea of self-exaltation. In like manner, Hope is the pleasurable contemplation of future enjoyment; Fear is the painful contemplation of future evil; and Cautiousness is the combination of the desire to avoid anticipated pain, with the pleasurable contemplation (an extremely strong feeling in many individuals) of precautions adapted to ward it off.—The same view may be applied to the love of Order, of Possessions, of Country, of Wit, of Humour, &c., and

* There are individuals who never manifest the least degree of *physical* combativeness, who yet show a remarkable love of opposition in all their *psychical* relations with others. That objections will be raised by such persons to *any* plan that may be proposed, we may always feel sure, though we may not have the remotest idea as to what the objection may be in each particular case. Persons in whom this tendency exists in a less prominent degree, are apt to see objections and difficulties *first*, although their good sense may subsequently lead them to consider these as of less account, or to be outweighed by the advantages of the scheme. Such was the case with the late Sir Robert Peel. On the other hand, those who are spoken-of as of *sanguine* temperament, are apt to lose sight of the intervening difficulties, in the pleasurable anticipation of the *result*.

to many conditions usually considered as purely Intellectual. And, in fact, the association of any kind of that *Emotional sensibility* (§ 602) of which pleasure and pain afford the simplest type, with *any idea*, or *class of ideas*, gives to it an Emotional character; so that Emotional states are not by any means limited within the categories under which Psychologists have attempted to range them; these being, for the most part, *generic terms*, which comprehend certain groups of ideas bearing more or less similarity to each other, but not by any means including all possible combinations.*

620. By those who regard the Propensities, Moral Feelings, &c., as simple states of mind, it is usually said that their indulgence or exercise is attended with pleasure, and the restraint of them with pain. But, if the view here taken be correct, it is the very co-existence of pleasurable or painful feelings with the idea of a given object, that causes *desire* or *aversion* as regards that object; since the mind instinctively pursues what is pleasurable, and avoids what is painful. And thus, according to the readiness with which these different classes of ideas are excited in different minds (partly depending upon original constitution, and partly upon the habitual direction of the thoughts), and to the respective degrees in which they respectively call-forth the different kinds of Emotional sensibility (as to which there is obviously an inherent difference amongst individuals, analogous to that which exists with regard to the feelings of pleasure or pain excited by external sensations, sights, sounds, tastes, odours, or contacts), will be the disposition of the mind to entertain them, the frequency with which they will be brought before the mental view, and the influence which they will exert in the determination of our conduct.

621. The influence of Emotional conditions, when strongly excited, in directly producing involuntary movements, is readily explained on the idea that the Sensory Ganglia are the seat of all consciousness, and the Cranio-Spinal axis the real source of all movement. For there is no more difficulty in understanding, that the excitement of peculiar states of consciousness in the Sensorial centres through the instrumentality of the Cerebrum, should give rise to automatic movements, than that such movements should follow similar states of consciousness when excited by impressions made upon the organs of vision, hearing, &c. And the correspondence is seen to be very close, when the idea (as is doubtless the case in some instances) is very nearly akin to the sensation. Thus, the laughter excited by the act of tickling, is a purely consensual movement (§ 538); but, in a very 'ticklish' person, the mere *idea* of tickling, suggested by pointing a finger at him, is sufficient to provoke it. So, again, as Laughter may be excited by odd sights or sounds which do not in themselves excite any ideational state, but which act at once upon the 'sense of the ludicrous,' the same action may be called-forth by the vivid

* The truth of this statement must be apparent to all who are familiar with the manifestations of Eccentricity and Insanity; for we frequently see pleasurable feelings associating themselves with ideas, which to ordinary minds appear *indifferent*, or are even regarded with pain; and thus are engendered motives, which exert a most powerful influence over the conduct, and which, if not kept in restraint by the Will, render the whole being their slave.—It may be also remarked, in this place, that the impossibility of classing all the Emotional states of mind under a limited number of categories, constitutes a most serious and fundamental objection to any system, which professes to mark-out in the Cerebrum distinct seats for the Animal Propensities, Moral Feelings, &c.

recollection of these occurrences, which, being attended with a state of the sensorium corresponding to that originally produced by the sensation, gives-rise to the same involuntary cachinnation. But Laughter may also be excited by ideas that are much more removed from actual sensations, as, for example, by those unexpected combinations of ideas of a purely intellectual nature, which we designate as 'witty;' and here too, we may recognize the very same *modus operandi*. For the mere sound or sight of the *words* excites no feeling of the ludicrous; the sensation must develope an *ideational* change; and it is the latter alone, which, re-acting downwards upon the Sensorium, and there becoming associated with the Emotional sensibility, excites the impulse to laugh. The same might be shown to be the case with regard to the act of Crying, which may be either purely consensual, being excited by painful sensations, or may be induced by the vivid recollection of past or the anticipation of future sensations; or may be excited by ideas which have no direct relation to sensational states. Again, the movements which take place under the violent excitement of the passion of Anger are of the same involuntary character; being directly prompted by feelings which may be called-up either by external sensations, or by internal ideas that have a like power of exciting them. Thus the passionate man who receives a blow, instinctively makes another blow in the direction from which it seemed to him to come, without any thought of whether the blow was accidental or intentional; and the idea of an insult, which is a source of mental disturbance, may excite the very same movement, although no bodily suffering had been experienced. In states of excessive Sexual excitement, again, the desire, which arises out of the idea of the object (§ 619), produces involuntary movements corresponding to those which are ordinarily linked on to the actual sensations alone. There are many of the movements of Expression, which are referable in like manner to states of consciousness, whether pleasurable or painful, which may arise from ideational as well as from sensational conditions. Thus, as we have seen, the Cheerful aspect of some individuals is due to a sense of general *physical* well-being, and is altogether discomposed by anything which disturbs this; whilst in others, it may proceed from a happy frame of mind (which may be partly the result of original constitution, and partly of habitual self-direction), disposing them to take the cheerful view of everything that affects themselves or others, notwithstanding (it may be) great bodily discomfort. And the reverse aspect of Gloom may in like manner proceed alike from bodily or from mental uneasiness.—All these facts point, therefore, to the conclusion, that whether the elementary states of Emotional sensibility associate themselves with Sensations, with Perceptions, or with Ideas, they are simple *modes of consciousness*, the organic seat of which must be in the Sensorial centres; and this corresponds well with the character of the purely Emotional movements, which, as we have seen, are closely allied to the Sensori motor, in the directness with which they respond to the stimuli that excite them.

622. That the Emotional and Volitional movements differ as to their primal sources, is obvious, not merely from the fact that they are frequently in antagonism with each other, the Will endeavouring to restrain the Emotional impulse, and either succeeding in doing so, or

being vanquished by the superior force of the latter,—but also from the curious fact, which Pathological observation has brought to light, that muscles which will still act in obedience to Emotional impulses, may be paralysed to Volitional, and *vice versâ*. Thus for example, the arm of a man affected with hemiplegia, which no effort of his will could move, has been seen to be violently jerked under the influence of the mental agitation consequent upon the sight of a friend. And in the case of softening of the Spinal Cord already referred-to (§ 503 *note*), the choreic movements, which were brought-on by the mere approach of any one to the patient's bed, and still more strongly by putting a question to him, were most violent in the lower limbs, over which he had not the least voluntary power.—It is in the different forms of paralysis of the Facial nerve, however, which is the one most peculiarly subservient to the movements of Expression, that we have the best evidence of this distinctness. For it sometimes happens that the muscles supplied by this nerve are paralysed so far as regards the Will, and yet are still affected by Emotional states of mind, and take their usual part in the automatic actions of Respiration, &c., retaining also their usual tension, so that no distortion is apparent unless Voluntary movements be attempted: thus, to select an action which may be performed either consensually, emotionally, or voluntarily, a patient affected with this form of paralysis cannot close the eyelid by an act of his will, although he winks when he feels the uneasy sensation that excites the action, and shuts the lids when the sudden approach of an object to the eye excites the fear of injury to that organ. On the other hand, the paralysed condition may exist in regard to the automatic and emotional actions only, so that the muscles lose their tension, the mouth is drawn to one side, the movements of expression are not performed, and there is no involuntary winking: yet the Will may still exert its accustomed control, and may produce that closure of the lids which does not take place in respondence to any other impulse.* —It has been inferred by Dr. M. Hall,† from cases of this kind, that the Emotional actions are among those which are performed by his 'true spinal' system of nerves, as distinct from the sensori-volitional, and that they therefore fall under the general category of excito-motor actions. But it is obvious that they differ from these in their dependence, not merely upon sensations, but also upon higher states of mind; and there is no proof whatever, that the same nerve-fibres do not serve for the conduction of the motor impulses proceeding from the two different mental sources, Volition and Emotion, as we have seen that they probably do for the volitional and automatic impulses (§ 550).‡

623. The Emotions are concerned in Man, however, in many actions,

* See the detailed accounts of such cases in Sir C. Bell's work on "The Nervous System of the Human Body;" also "Brit. and For. Med. Rev.," vol. iv. p. 500, and vol. xiii. p. 553.

† "Memoirs on the Nervous System," 1837, pp. 94, *et seq.*

‡ In the earlier editions of this Treatise, the Author maintained, upon the principles advocated by Dr. M. Hall, that there must be distinct centres and conducting fibres for Volitional, Emotional, and Reflex movements. Having since arrived at what he believes to be a much simpler explanation of the phenomena, and one more in accordance with the facts of the case, he has not hesitated to make known the change in his convictions; and would hope that he may induce those who may have accepted his previous opinions, to reconsider the subject under the aspect in which he has now placed it.

which are in themselves strictly voluntary Unless they be so strongly excited as to get the better of the Will, they do not operate downwards upon the Automatic centres, but upwards upon the Cerebral, supplying the *motives* by which the course of thought and of action is habitually determined (§ 676). Thus, of two individuals, with differently constituted minds one shall judge of everything through the medium of a gloomy morose temper, which, like a darkened glass, represents to his judgment the whole world in league to injure him; and his determinations being all based upon this erroneous view, its indications are exhibited in his acts which are themselves, nevertheless, of an entirely-voluntary character. On the other hand, a person of a cheerful, benevolent disposition, views the world around as through a Claude-Lorraine glass, seeing everything in its brightest and sunniest aspect, and, with intellectual faculties precisely similar to those of the former individual, he will come to opposite conclusions; because the materials which form the basis of his judgment are submitted to it in a very different condition. Various forms of Moral Insanity exhibit the same contrast, in a yet more striking light (§ 707). We not unfrequently meet with individuals, still holding their place in society, who are accustomed to act so much upon *impulse* and to be so little guided by *reason*, as to be scarcely regarded as sane; and a very little exaggeration of such a tendency causes the actions to be so injurious to the individual himself, or to those around him, that restraint is required, although the intellect is in no way disordered, nor are any of the feelings perverted. Not unfrequently we may observe similar inconsistencies, resulting from the habitual indulgence of one particular feeling or from a morbid exaggeration of it. The mother who, through weakness of Will, yields to her instinctive fondness for her offspring, in allowing it gratifications which she knows to be injurious to it, is placing herself below the level of many less gifted beings. The habit of yielding to a natural infirmity of temper often leads into paroxysms of ungovernable rage, which, in their turn, pass into a state of maniacal excitement. It is not unfrequently seen, that a delusion of the *intellect* (constituting what is commonly known as Monomania) has in reality resulted from a disordered state of the *feelings*, which have represented every occurrence in a wrong light to the mind of the individual (§ 709). All such conditions are of extreme interest, when compared with those which are met with amongst idiots, and animals enjoying a much lower degree of intelligence; for the result is much the same, in whatever way the balance between the feelings and the judgment (which is so beautifully adjusted in the well-ordered mind of Man) is disturbed; whether by a diminution of the Voluntary control, or by an undue exaltation of the Emotions and passions.

624. This double *modus operandi* of the Emotional consciousness,—*downwards* through the nerve-trunks upon the Muscular apparatus, and also upon many of the Organic functions (CHAP. XV),—and *upwards* upon those Cerebral actions which give rise to the higher states of Mental consciousness,—affords a satisfactory explanation of a fact which is practically familiar to most observers of Human nature, namely, that violent excitement of the feelings most speedily subsides, when these unrestrainedly expend themselves (so to speak) in their natural expressions. Thus it may be commonly noticed that those who are termed *demonstrative*

persons are less firm and deep in their attachments, than those who manifest their feelings less; for, without any real insincerity or intentional fickleness, the strongly excited feelings of the former are rapidly toned down by the expenditure of the impulse to action which they have generated; whilst in the latter the very same feelings, acting internally, acquire a permanent place in the psychical nature, and habitually operate as motives to the conduct. So, again, persons who are 'quick-tempered,' manifesting great irascibility upon small provocations, real or supposed, are usually soon appeased, and soon forget the affront; whilst those who make little or no display of anger, are very apt to brood-over and cherish their feelings of indignation, and may visit them upon the unfortunate object of them, when some favourable opportunity happens to occur, long after he had supposed that the occurrence which had given rise to them was forgotten. There is an instinctive restlessness, or tendency to general bodily movement, in some individuals, when they are suffering under emotional excitement; the indulgence of which appears to be a sort of safety-valve for the excess of nerve-force, whilst the attempt at its repression is attended with an increase in the excitement. Most persons are conscious of the difficulty of sitting still, when they are labouring under violent agitation, and of the relief which is afforded by active exercise; and this is particularly the case when the movements are such as naturally express the passion that is excited. Thus the combative propensities of the Irish peasant commonly evaporate speedily with the free play of the shillelagh; many irascible persons find great relief in a hearty explosion of oaths, others in a violent slamming of the door, and others (whose excitement is more moderate but less transient) in a prolonged fit of grumbling.* So, again, if a ludicrous idea be suggested to our consciousness, occasioning an impulse to laugh, a hearty 'guffaw' generally works-off the excitement, and we may be surprised a short time afterwards that such an absurdity should have provoked our risibility; but if we restrain the explosion, the idea continues to 'haunt' us, and is continually perturbing our trains of thought until we have given free vent to the expression of it. Again, it is well known that the depressing emotions are often worked off by a fit of crying and sobbing; and the 'relief of tears' seems manifestly due to the expenditure of the pent-

* This view is most fully confirmed by certain phenomena of Insanity. It is a doctrine now generally received among practical men, that paroxysms of violent emotional excitement are much more likely to subside, when they are allowed to 'work themselves off' freely, without any attempt at mechanical restraint; and maniacal patients are now placed in all well-managed Asylums, in padded rooms, in which their movements can do no injury to themselves or others. The following case was related to the Author by his friend Dr. Howe, of Boston, N.E., the instructor of Laura Bridgman. A half-idiotic youth in the Lunatic Asylum of that place, was the subject (like many in his condition) of frequent and violent paroxysms of anger; and with the view of moderating these, it was suggested that he should be kept for some time every day in rather fatiguing exercise. Accordingly he was employed for two or three hours daily in sawing wood, to which task he made no objection; and the paroxysms of rage never displayed themselves, except on Sundays, when his employment was intermitted. It having been considered, however, that it was better for him to spend a part of that day in sawing wood, than to be irascible during the whole of it, his occupation was continued through the whole week, when he became completely tamed-down, and never gave any more trouble by his passionate displays. This case appears to the Author a most valuable confirmation of the doctrine laid down in the text; which is one whose practical bearings are most important.

up nerve-force, in the production of an increased secretion. It is noticed in this case, too, that the absence of any such external manifestation of the depressing emotions, gives them a much greater influence upon the course of thought, and upon the bodily state of the individual. Those who really 'die of grief,' are not those who are loud and vehement in their lamentations, for *their* sorrow is commonly transient, however vehement and sincere while it lasts; but they are those who have either designedly repressed any such manifestations, or who have experienced no tendency to their display; and their deep-seated sorrow seems to exert the same kind of anti-vital influence upon the organic functions that is exercised more violently by 'shock,' producing their entire cessation without any structural lesion.*

625. The influence of Emotional excitement may operate upon the muscles, however, not only in giving-rise to movements which can be attributed to no other source, but also in affecting the power of the Will over the muscular system, by intensifying or weakening its action. For there can be no doubt that, under the strong influence of one class of feelings, the Will can effect results such as the individual would scarcely even attempt in his calmer moments; whilst the influence of another class of feelings is exercised in precisely the opposite direction, weakening or even paralysing the force which was previously in full activity. But the same emotion does not always act in the same mode; thus, the fear of danger may nerve one man to the most daring and vigorous efforts to avert it, whilst another is rendered powerless, and gives way to unavailing lamentations; and the ardent anticipation of success may so unsettle the determinative energy of one aspirant, as to prevent him from attaining his object, whilst another may only be sustained by it in the tedious struggle of which it is the final reward. Now in order that this variety may be explained, and the *modus operandi* of the Emotions on strictly Volitional actions may be duly comprehended, we must here state two of the essential conditions of the latter; one of which is, that there should be not merely a distinct conception of the purpose *to be* attained, but also a belief that the purpose *will* or at least *may* be attained; whilst the other is, that the mental energy should be to a great extent withdrawn from other objects, and should be *concentrated* upon that towards which the Will is directed.—It is within the experience of every one, that there is nothing which tends so much to the success of a volitional effort as a *confident expectation* of its success; whilst nothing is so likely to insure failure, as the apprehension of it. Now, in so far as regards this mode of their operation alone, the tendency of the cheerful or joyous emotions being to suggest and keep-alive the favourable anticipations, whilst that of the depressing emotions (of almost any kind) is to bring before the

* The Author once heard the following singular case of this kind. One of two sister orphans, who were strongly attached to each other, became the subject of consumption; she was most tenderly nursed by her sister during a long illness, but on her death the latter, instead of giving way to grief in the manner that might have been anticipated, appeared perfectly unmoved, and acted almost as if nothing had happened. About a fortnight after her sister's death, however, she was found dead in her bed; yet neither had there been any symptoms during life, nor was there any post mortem appearance which in the least degree accounted for this event; of which no explanation seemed possible, except the depressing influence of her pent-up grief upon her frame generally, through the nervous system.

view all the chances of failure, the former will increase the power of the volitional effort, and the latter will diminish it. And they exert also a direct influence on the physical powers, through the organs of circulation and respiration; the heart's impulses being more vigorous and regular, and the aeration of the blood being more effectually performed, in the former of these conditions than in the latter. But an altogether contrary effect may be produced by the operation of these two classes of Emotions through the second of the above channels. For the more completely the mental energy can be brought into one focus, and all distracting objects excluded, the more powerful will be the volitional effort; and the effect of emotional excitement will thus in great degree depend upon the intellectual constitution which the individual may happen to possess. For if he have a considerable power of abstraction and concentration, and a full conviction that he has selected the best or the only means to accomplish his end, the intensest fear of the consequences of failure will only increase the force of the motive which prompts the effort; and the whole energy of which his nature is capable, will display itself in the attempt. In a man of this temperament, the most joyous anticipation of success will produce no abatement of his efforts, no distraction of his attention, but will rather tend to keep him steady to his purpose until it shall have been accomplished; and then only does he dare to abandon himself to the current of ideas which rolls-in upon his consciousness, so soon as his attention is free to entertain them. But the mind which is deficient in the power of concentrativeness, is lamentably deranged by any kind of emotional excitement, in the performance of any volitional effort. For the fear of failure is constantly suggesting to him new distresses, weakens his confidence in any method suggested for his action, and makes him direct his attention, not to some fixed plan as the best or the only feasible one, but to any and every means that may present a chance of success, or may even serve to avert his thoughts from the dreaded catastrophe; whilst, on the other hand, the joyous anticipation of success leads him to allow his thoughts to direct themselves towards all its agreeable consequences, instead of fixing his intellectual and volitional energy upon the means by which success is to be attained.

626. If this be the true solution of the mode in which the Emotions chiefly affect the exercise of our Volitional powers, we should expect that similar effects might be induced, without any Emotional excitement, by means which affect the Intellectual consciousness alone; and that thus an action otherwise impossible to the individual may be performed by him, if (1) his mind be possessed with a full assurance of success, and (2) if his entire motor energy be concentrated in the single exertion; whilst, on the other hand, an action which can be ordinarily performed with the greatest facility may become absolutely impossible to him, if (1) his mind be entirely possessed with the idea of its impossibility, or even (2) if, while his judgment entertains doubts of success, his attention be distracted by a variety of objects, so that he cannot bring it to bear upon the one effort which may alone be needed.—Now experience shows that such is really the case; but as this experience is the most remarkable in regard to certain states of the mind in which these two modes of operation may be worked in combination, it will be sufficient to refer to them for the demonstration (§§ 666, 672).

627. *Succession of Psychical States.*—The Mind, when not engaged in Sensational or Perceptive acts, is incessantly occupied in *thinking*, its whole inner life being *a succession of Ideas and Emotions*, only suspended by Sleep and Death, or interrupted by the concentration of its attention on impressions newly received from external objects. Now whatever difference of opinion there may be, in regard to the degree in which the ordinary laws of Causation are applicable to Mental phenomena (in other words, as to how far each state of consciousness may be considered as *determined* by its antecedents), all are agreed that, in each individual, there are certain *uniformities of mental action*, which constitute what is termed his Character; and that these uniformities are in part the result of his congenital constitution, and in part of the circumstances in which he may have been placed; both of which sets of influences concur to establish certain *tendencies to thought*, which manifest themselves in his ordinary course of action, as well as in the more express products of his Mental labour.—Thus we find the Intellectual character of each individual to consist in the predominance of certain 'Intellectual Faculties,' which, as we shall hereafter see, are only designations for particular modes of Intellectual activity; and hence we can predicate, to a certain extent, the nature of the result at which his Mind will arrive by its exercise upon a given subject. So, again, his Moral character will depend upon the combination which may exist in his individual nature, of those Emotional tendencies, which not merely furnish a large share of the governing motives of his actions, but which also contribute in a very important measure to the direction of his thoughts, in virtue of that law of our nature which leads us to dwell on those subjects wherewith pleasurable feelings are associated, and to withdraw our contemplation from those which are accompanied with feelings of pain or discomfort.—Now in so far as the succession of our thoughts takes-place in accordance with the *habitudes* which are thus determined, may we consider that our character is formed *for* us, rather than *by* us; and may look upon our Mental activity, whether it manifest itself in the form of Thought or of Feeling, as no less *Automatic* than the instinctive operations of the lower animals, though far more elevated in its nature.

628. But our own consciousness tells us that there is something in our Psychical nature, that is beyond and above this automatic exercise of our powers; and that the direction of our thoughts, within certain limits, is placed under the control of the Will. These limits are partly universal, and partly peculiar to the individual. It may be stated as a fundamental axiom, that the Will can *originate* nothing; its power being limited to the *selection* and *intensification* of what is actually before the consciousness. Thus no one has ever *acquired* the creative power of Genius, or *made himself* a great Artist or a great Poet, or *gained by practice* that peculiar insight which characterises the original Discoverer; for these gifts are mental instincts or intuitions, which may be developed and strengthened by due cultivation, but which can never be generated *de novo*. It not unfrequently happens, however, that such gifts lie dormant, until some appropriate impression excites them to activity; and it is then that we most obviously see what the Will can do to perfect and utilize them, by exercising them under circumstances most fitted to expand and elevate, and by restraining them from all that would limit or

debase. In regard to every kind of mental activity that does *not* involve origination, the power of the Will, though limited to selection, is otherwise unbounded. For although it cannot directly bring objects before the consciousness which are not present to it, yet it can concentrate the mental gaze (so to speak) upon any object that may be within its reach, and can make use of this, as we shall hereafter see, to bring-in other objects by suggestion or association. And, moreover, it can virtually determine what shall *not* be regarded by the Mind, through its power of keeping the attention fixed in some other direction; and thus it can subdue the force of violent impulse, and give to the conflict of opposing motives an issue quite different from that which would ensue without its interference. This exercise of the Will, moreover, if habitually exerted in certain directions, will tend to form the 'character,' by establishing a set of *acquired habitudes;* which, no less than those dependent upon original constitution and circumstances, help to determine the consequences of any particular state of the thoughts and feelings.

629. We have seen that, in those actions of the Nervous system (as of other parts of the body) in which the Will is not concerned, we have simply to consider the two elements of which we take account in all scientific inquiry; namely, the *force* that operates, and the *organized structure* on and through which it operates,—in other words, the dynamical agency, and the material conditions. And if we could imagine a being to grow-up from infancy to maturity, with a mind in the state of that of a 'biologized' subject (§ 672), we should see that it would be strictly correct to speak of his character as formed *for* him and not *by* him; all his thoughts, feelings, and actions being but the reflex of his own nature upon the impressions made upon it; and that nature being determined in part by original constitution, and in part by the mode in which it is habitually called into action.—This last condition is one that is peculiar to a living and growing organism; and it is one which cannot be too strongly or too constantly kept in mind. A mere inorganic substance reacts in precisely the same mode to mechanical, chemical, electrical, or other agencies, however frequently these are brought to bear upon it, provided it has been restored to its original condition; thus water may be turned into steam, the steam condensed into water, and the water raised into steam again, any number of times, without the slightest variation in the effects of the heat and cold which are the efficient causes of the change. But every kind of activity peculiar to a living body, involves (as has been repeatedly shown) a change of structure; and the formation of the newly-generated tissue receives such an influence from the conditions under which it originates, that all its subsequent activity displays their impress. The readiness with which particular habitudes of thought are formed, varies greatly in different individuals and at different periods of life. As a general rule, it is far greater during the period of growth and development, than after the system has come to its full maturity; and remembering that those new functional relations between other parts of the Nervous system, which give rise to the 'secondarily-automatic' movements or acquired instincts, are formed during the same period, it seems fair to surmise that the substance of the Cerebrum *grows to* the conditions under which it is habitually exercised. Hence, as its subsequent nutrition (according to the general laws of

assimilation, § 346) takes place on the same plan, we can understand the well known force of early associations, and the obstinate persistence of early habits of thought.

630. This view, indeed, must be extended to that remarkable *hereditary transmission* of psychical character, which presents itself under circumstances that entirely forbid our attributing it to any agency that can operate subsequently to birth, and which it would seem impossible to account-for on any other hypothesis, than that the formative capacity of the germ determines the subsequent development of the Brain, as of other parts of the body, and (through this) its mode of activity, in accordance with the influences under which that germ was first impregnated. And thus what we speak-of as the 'original constitution' of each individual, is in great part (if not entirely) determined by the conditions, dynamical and material, of the parent-organisms; a convincing proof of which general fact, is afforded by a careful examination of the parental constitution and habits, in a large proportion of cases of Idiocy.* Whatever may be the congenital constitution, however, there can be no question that this is liable to great modification from external influences, both such as directly affect its physical conditions, and such as operate through the consciousness, in determining the course of thought and feeling, before the individual has acquired any self-determining power. Of this influence of physical agencies, we have a typical example in the phenomena of Cretinism; since, although the conditions under which that state is developed have not yet been precisely determined, no one can reasonably doubt that they are such as act in the first instance in modifying the nutrition and activity of the bodily organism in general, and of the Nervous system in particular.

631. But, further, the psychical tendencies of every one undergo a consecutive change in the progress of life. Infancy, Childhood, Youth, Adolescence, Adult age, the period of Decline, and Senility, have all their characteristic phases of psychical as of physical development and decline; and this is shown, not merely in the general advance of the Intellectual powers up to the period of middle life, and in their subsequent decay, but in a gradual change in the balance of those springs of action which are furnished by the Emotional states, the pleasures and pains of each period being (to a certain extent) of a different order from those of every other. This diversity may be partly attributed to changes in the physical constitution; thus, the sexual feeling which has a most powerful influence on the direction of the thoughts in adolescence, adult age, and middle life, has comparatively little effect at the earlier and later periods. So, again, the thirst for novelty, and the pleasure in mental activity, which so remarkably characterize the young, when contrasted with the obtuseness to new impressions and the pleasure in tranquil occupations, which mark the decline of life, may perhaps be attributed, in part at least, to the greater activity of the changes, both of disintegration and reparation, of which the Nervous system (in common with the rest of the organized fabric) is the subject during the earlier part of life, and to its diminished activity as years

* A most valuable collection of data on this subject is afforded by Dr. Howe's admirable 'Report on Idiocy' made to the Legislature of Massachusetts, of which an abstract is contained in the "American Journal of the Medical Sciences," April, 1849.

advance. But there are other changes which cannot be so distinctly traced to any physical source, but which yet are sufficiently constant in their occurrence to justify their being regarded as a part of the developmental history of the psychical nature; so that each of the 'Seven Ages of Man' has its own character, which may be with difficulty defined in words, but which is recognized by the apprehension, as it forces itself upon the experience, of every one.

632. *Laws of Association.*—The most powerful agency in the Automatic determination of the succession of our Mental states, is undoubtedly that tendency which exists in all Minds that have attained the Ideational stage of development, to the *Association of Ideas;* that is, to the formation of such a connection between two or more ideas, that the presence of one tends to bring the other also before the consciousness; or, in other words, each tends to *suggest* the other. Certain Laws of Association, expressive of the conditions under which this connection is formed, and the mode in which it acts, have been laid down by Psychologists; and these may be concisely stated as follows:—
1. *Law of Contiguity.* Two or more states of consciousness, habitually existing together or in immediate succession, tend to cohere, so that the future occurrence of any one of them is sufficient to restore or revive the other. It is thus (to take a simple illustration) that the impressions made upon our sensational consciousness by natural objects, which are usually received through two or more senses at once, are compacted into those aggregate notions, which, however simple they may appear, are really the result of the intimate combination of many distinct states of ideation. Thus our notion of the *form* of an object is made up of separate notions derived from the visual and muscular senses respectively; our notion of the character of its surface, from the combination of impressions received through the visual and tactile senses; and with both of these our notion of colour, as in the case of an orange, may be so blended, that we do not readily conceive of its characteristic form and surface, without also having before our minds the hue with which these have been always associated in our experience. So, again, the external aspect of a body suggests to our minds its internal arrangement and qualities, such as we have before found them invariably to be; thus, to use the preceding illustration, the shape and colour of the orange bring before our consciousness its fragrant odour and agreeable taste, as well as the internal structure of the fruit. And our notion of 'an orange' must be considered as the aggregate of all the preceding ideas.—Not only the different ideas excited by one object, but those called-up by objects entirely dissimilar, may thus come to be associated, provided that the mind has been accustomed to the presentation of them in frequent contiguity one with the other. Such conjunctions may be natural, that is, they may arise out of the 'order of nature;' or they may be artificial, being due to human arrangements; all that is requisite is, that they should have sufficient permanence and constancy to habituate our minds to the association. Of this law of contiguity, moreover, we have a most important example in the association which the mind early learns to form between successive *events*, so that when the first has been followed by the second a sufficient number of times to form the association, the occurrence of the first suggests the *idea* of the

second; if that idea be verified by its occurrence, a definite *expectation* is formed; and if that expectation be unfailingly realized, the idea acquires the strength of a *belief*. And thus it is that we come to acquire that part of the notion of 'cause and effect,' which consists in invariable and necessary sequence, and to form our fundamental conception of the invariability of Nature. It is by the same kind of operation again, that we come to employ words as the symbols of ideas, for the convenience of intercommunication and reference (§ 613); a certain number of repetitions of the sound, concurrently with the sight of the object, or the suggestion of the notion of that object, being sufficient to establish the required relation in our minds. Of the large share which this kind of action takes in the operations of *Memory* and *Recollection*, evidence will be presently given.*

633. But a not less important 'tendency to thought,' and one whose operation is more concerned in all the higher exercises of our Reasoning faculties, is that which may be expressed under the designation of the *Law of Similarity*, and which consists in the general fact that any present state of consciousness tends to revive previous states that are similar to it. It is thus that we instinctively invest a new object with the attributes we have come to recognize in one that we have previously examined, to which the new object bears such a resemblance, that the sight of the latter suggests those ideas which our minds connect with the former. Thus, we will suppose a man to have once seen and eaten an orange; when he sees an orange a second time, although it may be somewhat larger or smaller, somewhat rougher or smoother, somewhat lighter or darker in hue, he recognizes it as 'an orange,' and mentally assigns to it the fragrance and sweetish acidity of the one which he had previously eaten. But if, instead of being yellow, the fruit were green, he would doubt of its being an orange; and if assured that it still was, but had not come to maturity, he would no longer expect to find it sweet, the notion of intense acidity being suggested to his mind by his previous experience of other green and unripe fruit.—It is in virtue of this kind of action, that we extend those elementary notions which are primarily excited by sensation, to new objects. Thus,

* It is a curious example of the automatic action of the mind, in accordance with the laws of Association, that a young child who happens to possess two modes of communicating its ideas, seems unconsciously to select that which is conformable to the receptivity of the person addressed.—Thus, Dr C. B. Radcliffe ("Philosophy of Vital Motion," p. 157) mentions the case of a child belonging to an English family resident in Germany, who had acquired the power of speaking on ordinary matters either in German or English, without confusing the words or idioms; but who yet seemed invariably compelled to reply in the language of the person he was addressing. Thus, in conveying a message to his German nursery maid, he delivered it in German, though it had been received the moment previously in English; but on returning to the English family in the parlour, if asked what the maid had said, he answered in English as often as the question was proposed in English, and even though pressed to give the words he had heard in the nursery, he still continued to do the same, without seeming to be aware of the difference. But if the question was put to him in German, the answer was in German, there being the same inability to reply in English, as there had previously been to give a German answer to the English question. So Dr Kitto ("The Lost Senses," vol. i. p. 97) tells us that his children, in their successive infancies, would begin to imitate the finger-language *whenever they saw him*, even whilst they were yet in arms, and could have had no true cognizance of his peculiar condition.—The more carefully, indeed, the actions of Childhood are observed, the more obvious does it become that they are solely prompted by ideas and feelings which automatically succeed one another, in uncontrolled accordance with the laws of suggestion.

the idea of roundness (like other notions of form) is originally based on the combination of the muscular and visual sensations, and must be first acquired by a process of considerable complexity; but when once derived from the examination of a single object, it is readily extended to other objects of the same character.—So, again, it is by the operation of this mental tendency, that we recognize similarity where it exists in the midst of difference, and separate the points of agreement from those of discordance; and this, again, not merely as regards objects which are before our consciousness at the same time or in close succession, but also with regard to all past states of consciousness. It is thus that we *identify* and *compare*, that we lay the foundations of classification, and that we recover all past impressions which have anything in common with our present state of consciousness. The intensity of this tendency, and the habitual direction which it takes, vary extremely in different individuals. Some have so great an incapacity for recognizing similarity, that they can only perceive it when it is in marked prominence, their minds taking much stronger note of differences; whilst others have a strong bias for the detection of resemblances and analogies, and discover them where ordinary minds cannot recognize them. Some, again, address themselves to the discovery of similarity among objects of sense, whilst others study only those ideas which are the objects of our internal consciousness; and it is in the detection of what is essentially similar among the latter, that all the higher operations of the intellect essentially consist. Even here we find that some are contented with superficial analogies, whilst others are not satisfied until they have penetrated by analysis to the depths of the subject, and are able to compare its fundamental idea with others of like kind.—It may be remarked that this mode of action of the mind is in some degree opposed to the preceding; for whilst *contiguity* leads to the arranging of ideas as they happen to present themselves in natural juxtaposition, and thus to induce a routine which is often most unmeaning (§ 676), *similarity* breaks through juxtaposition, and brings together like objects from all quarters.

634. It is this habit of mind, which is of essential value in all the sciences of *Classification* and *Induction*. Thus, in the formation of generic definitions to include the characters which a number of objects have in common, their subordinate differences being for a time left out of view, we are entirely guided by the recognition of similarity between the objects we are arranging; and the same is the case in the formation of all the higher groups of families, orders, and classes, the points of similarity becoming fewer and fewer as we proceed to the more comprehensive groups, whilst those of difference increase in corresponding proportion. The sagacity of the Naturalist is shown in the selection of the *best* points of resemblance, as the foundation of this classification; the value of characters being determined, on the one hand by their constancy, and on the other by their degree of coincidence with important features of general organization or of physiological history.* In the

* Thus, for example, it is now generally admitted amongst Zoologists, that the Implacental Mammalia should constitute a separate sub-class, in virtue of the peculiar conformation of their generative apparatus, instead of being distributed among other Orders, as they were left by Cuvier.

determination of Physical laws, the process is somewhat of the same kind; but the similarities with which we have here to do, are not, as in the preceding case, objective resemblances, but exist only among our subjective ideas of the nature and causes of the phenomena brought under our consideration. Thus, there is no obvious relation between the fall of a stone to the Earth, and the motion of the Moon in its elliptical orbit around it, but the penetrating mind of Newton detected a relation of *common causation* between these two phenomena, which enabled him to express them both under one law. It was by a similar intellectual perception of similarity, that Franklin was led to determine the identity of Lightning with the spark from an Electrical machine. And it would be easy to show that it has been in their extraordinary development of this power of recognizing *causative* similarity, leading to a kind of Intuitive perception of its existence where as yet no adequate ground can be assigned by the Reason for such a relationship, that those men have been eminent, who have done the most to advance science by the process of inductive generalization.

635. The same kind of mental action is also employed in the contrary direction; namely, in that application of general laws to particular instances, which constitutes *Deductive Reasoning;* and in that extension of generic definitions to new objects, which takes-place upon every discovery of a new species. We may trace it again, even in the extension of the meaning of words so as to become applicable to new orders of ideas, in consequence of the resemblance which the latter are felt to bear to those of which the words were previously the symbols; as in the application of the word 'head,' which primarily designated the most elevated part of the human body, in such phrases as the 'head of a house,' the 'head of a state,' the 'head of an army,' the 'head of a mob,' in each of which the idea of superiority and command is involved; or in the phrases the 'heads of a discourse,' or the 'heads of an argument,' in which we still trace the idea of authority or direction; or in the phrases the 'head of a table,' the 'head of a river,' in which the idea of superiority or origin comes to be locally applied; or in the 'head of a bed,' or 'head of a coffin,' in which we have the more distinct local association with the position of the head of man. Of the foregoing applications, those first cited belong to the nature of a metaphor, which has been defined to be "a simile comprised in a word;" and the judicious use of metaphors, which frequently adds force as well as ornamental variety to the diction, is most seen amongst those who possess a great power of bringing together the 'like' in the midst of the 'unlike.'

636. Every effort, in fact, to trace-out unity, consistency, and harmony, in the midst of the wonderful and (at first sight) perplexing variety of objects and phenomena amidst which we are placed, is a manifestation of this tendency of the Human Mind; and, when conducted in accordance with the highest teachings of the Intellect, or guided by that Intuition which in some minds supersedes and anticipates all reasoning, it enables us to rise towards the comprehension of that great Idea of the Universe, which we believe to exist in the Divine Mind in a majestic simplicity of which we can here but faintly conceive, and of which all the phenomena of Nature are but the manifestations

to our consciousness.—With this purely intellectual operation, there is frequently associated a peculiar feeling of pleasure, which constitutes a true Emotional state. All the discoveries of Identification, where use and wont are suddenly broken through, and a common feature is made known among objects previously looked on as entirely different, produce a flash of agreeable surprise, and the kind of sparkling cheerfulness that arises from the sudden lightening of a burden. There are few who devote themselves to the pursuit of Science, who do not experience this pleasure, either from the detection of new relations of similarity by their own perception of them, or in the recognition of them as developed by others. It is, however, much more intense in some minds than in others; and according to its intensity, will it act as a *motive* in the prosecution of scientific inquiry amidst discouragements and difficulties. It is recorded of Newton, that when he was bringing his great idea of the causative relation between terrestrial gravity and the motions of the heavenly bodies, to the test of calculation, his agitation became so great, that he could not complete the computation, and was obliged to request a friend to do so.

637. Although the single relations established between Ideas, either through Contiguity or through Similarity, may suffice for their mutual connection, yet that connection becomes much stronger when two or more such relations exist consentaneously. Thus, if there be present to our minds two states of consciousness, each of them associated, either by contiguity or similarity, with some third state that is past and 'out of mind' at the time, the compound action is more effective than either action would be separately; that is, although the suggestions might be separately too weak to revive the past state of consciousness, they reproduce it by acting together. Of this, which has been termed the *Law of Compound Association*, we have examples continually occurring to us in the phenomena of Memory; but it is especially brought into operation in the voluntary act of Recollection (§ 644).

638. Another mode in which the Associative tendency operates, is in the formation of aggregate conceptions of things that have never been brought before our consciousness by sensory impressions. This faculty, which has been termed that of *Constructive Association*, is the foundation of Imagination; and it is exercised in every other mental operation, in which we pass from the known to the unknown. When we attempt to form a conception, which shall differ from one that we have already experienced as a matter of objective reality, by the introduction of only a single new element,—as when we imagine a brick building replaced by one of stone, in every respect similar as to size and form,—we substitute in our minds the idea of stone for that of brick, and associate it by the principle of contiguity with those other ideas, of which that of the whole building is an aggregate. So, again, if we conceive a known building transferred from its actual site to some other already known to us, we dissociate the existing combinations, and keep-together the ideas which were previously separated, until their contiguity has so intimately united them, that the picture of the supposed combination may present itself to the mind exactly as if it had been a real scene which we had long and familiarly known. By a further extension of the same power, we may conceive the elements to be varied, as well as the mode of their

combination; and thus we may bring before our consciousness a representation, in which no particular has ever been present to our minds under any similar aspect, and which is, therefore, *as a whole* entirely new to us, notwithstanding that, when we decompose it into its ultimate elements, we shall find that each of these has been previously before our consciousness. Such a representation, by being continually dwelt-on, may come to have all the force and vividness of one derived from an actual sensory impression; and we can scarcely conceive but that the actual state of the Sensorium itself must be the same in both cases, though this state is induced in the one case by an act of Mind, and in the other by objective impressions.—A very common *modus operandi* of this 'constructive association,' is the realization of a landscape, a figure, or a countenance, from a pictorial representation of it. Every picture *must* be essentially defective in some of the attributes of the original, as, for example, in the representation of the *projection* of objects; and all, therefore, that the picture can do, is to *suggest* to the mind an idea, which it completes for itself by this constructive process, so as to form an aggregate which may or may not bear a resemblance to the original, according to the fidelity of the picture, and the mode in which it acts upon the mind of the individual. Thus to one person a mere sketch shall convey a much more accurate notion of the object represented, than a more finished picture shall give to another; because from practice in this kind of mental reconstruction, the former recognizes the true meaning of the sketch, and fills it up in his 'mind's eye,' whilst the latter can see little but what is actually before his bodily vision, and interprets as a literal presentation that which was intended merely as a suggestion. And it is now generally admitted, that in all the higher forms of representative Art, the aim should be, *not* to call into exercise the faculty of mere objective *realization*, but to address that higher power of *idealization*, which invests the conception suggested by the representation, with attributes more exalted than those actually possessed by the original, yet not inconsistent with them. It depends, however, as much on the mind of the individual addressed, as on that of the Artist himself, whether such conceptions shall be formed; since by those who do not possess this power, the highest work of Art is only appreciated, in so far as it enables them to realize the object which it may represent.

639. *Intellectual Faculties.*—Having thus pointed-out what may be considered the most elementary forms of Mental Action,* we shall briefly pass in review those more complex operations, which may be regarded as in great part compounded of them. The capacity for performing these is known as the Intellect or the Reasoning Power; and the capacities for those various forms of Intellectual activity, which it is convenient to distinguish for the sake of making ourselves more fully acquainted with them, are termed 'Intellectual Faculties.' It appears to the Author, however, to be a fundamental error to suppose, that the

* In the foregoing brief exposition of the laws and leading phenomena of Mental Association, the Author has derived great aid from the excellent article on 'The Human Mind,' contributed to Messrs. Chambers's "Information for the People," by his friend Mr Alexander Bain. Though not agreeing with all the views expressed in that article, the Author can cordially recommend the perusal of it to his readers.

entire Intellect can be split-up into a certain number of faculties: for each faculty that is distinguished by the Psychologist, expresses nothing else than a *mode of activity*, in which the whole power of the Mind may be engaged at once,—just as the whole power of the locomotive steam-engine may be employed in carrying it forwards or backwards, according to the direction given to its action. And if this be true, it must be equally erroneous to attempt to parcel-out the Cerebrum into distinct 'organs' for these respective faculties; the whole of it (so far as we can form a judgment) being called into operation, in every kind of intellectual process which occupies the attention at the time.

640. We have seen (§ 592) that the Consciousness may either be the *passive* recipient of the impressions of external objects, or may be *actively* directed towards them; and that in the latter state, it may single-out, from amongst a large number of impressions that present themselves simultaneously, some particular group, whose force becomes extraordinarily intensified, whilst the remainder pass entirely unnoticed. This state of *Attention* may be either *automatic* or *volitional;* being the result, in some instances, of the force of the impression, or of the peculiar attractiveness which the object may happen to possess for us; whilst it may also be induced by a determinate effort of the Will.—Now the very same difference between our states of Consciousness exists in relation to Mental operations, which may take place, on the one hand, without more than a passive cognizance of them on our own part; whilst, on the other hand, our Attention may be *actively* directed to them. And the same difference exists also in regard to the result of this direction; for the Mental state, of whatever nature it may be, upon which the Attention is fixed, becomes intensified to such a degree, as to exclude for the time the cognizance of other operations, and to acquire a peculiar power of suggesting *other* Mental states with which it may have some link of Association (§ 644). This direction of the Attention to states of Cerebral activity, may, like its direction to impressions received through the Organs of Sense, be either *automatic* or *volitional*. In the former case, the mind is engrossed for the time by some idea or emotion, in virtue of the intensity with which it has been called-up, or of the peculiar hold which it has upon our nature; and it may remain thus fixed, until this mental state shall have given-rise to some other, or shall have expended its force in bodily action, or until the attention has been determinately detached from it by an exertion of the Will. In the latter case, the mental gaze is fixed (so to speak) by a purposive effort, upon some single state, or on some class of ideas or feelings, which the individual desires to make the special object of contemplation; and it is by means of this *selecting* power, and of the tendency of the mental state thus intensified, to call-forth other states with which it has pre-formed links of association, that the Will possesses that power of *directing* the current of thought and feeling, which characterizes the fully developed Man (§§ 668, 669).—Thus it is in the degree of attention which we bestow, upon certain classes of ideas presented to us by Suggestion, that our power of *using* our Minds in any particular mode consists; and hence we see the fundamental importance of early learning to *fix* our attention, and to resist all influences which would tend to distract it. And this is essential, not merely to the advantageous employment of our Intellectual powers, but also to

the due regulation of our Emotional nature; for it is by fixing the attention upon those states of feeling which we desire to intensify, and conversely, by withdrawing it from those which we desire to repress (which is most easily effected by choosing *some other* object that exercises a healthful attraction towards us), that we can encourage the growth of what we recognize as worthy, and can keep in check what we know to be wrong or undesirable.

641. The intentional direction of the attention to *external objects* is what is commonly known as *Observation:* those men being designated as 'observant,' who do not allow their attention to be so far engrossed by one object or occurrence, or (as very frequently happens) by their own trains of thought, as to exclude the cognizance of what may be taking place around them; whilst those are spoken of as 'unobservant,' who by allowing their consciousness to remain fixed upon some one object or train of thought, prevent it from receiving a legitimate degree of influence from other impressions received and transmitted to the Sensorium by the organs of sense. That intentional direction of our consciousness to what is passing *within* us, which not merely intensifies the mental state, but separates and brings it forwards as a subject of observation, is usually designated as *Reflection*, but is more appropriately termed *Introspection*.

642. The reproduction of past states of consciousness by either of the forms of suggestive action already described, constitutes what is known as *Memory.** There seems much ground for the belief, that *every ideational* state which has even transiently occupied the consciousness is registered (so to speak) in the Cerebrum, and may be reproduced at some subsequent time, although there may be no consciousness of its existence in the mind during the whole intermediate period. Instances are of very frequent occurrence, in which ideas come-up before the mind during delirium or dreaming, and are expressed at the time or are subsequently

* It is commonly stated that Memory consists in the renewal of past sensations and of the ideas they have excited; but it may be questioned whether we can primarily reproduce anything else than the impressions left by *ideas*, and whether the renewal of sensations is not a secondary change, dependent upon the reaction of Ideational Cerebral states upon the Sensorium. For if we wish to reproduce any sensational state, — whether visual, auditory, olfactive, gustative, or tactile, — we first recall the notion of some object by which that state was formerly produced; and it is only by keeping that notion steadily before our consciousness, that we can bring ourselves to see, hear, smell, taste, or feel, as it were, what we desire to experience. Indeed it is not every one who can thus reproduce sensational states, the general notion being most commonly all that is arrived at. Of this we have a good illustration in the conception we form of the face of an absent friend; it being only a comparatively small number of persons who are able to reproduce the visual image with sufficient distinctness to serve as a model for delineation, although almost every one would be able to say how far such a delineation resembles their own conception of the countenance, and to point-out in what it might depart from this. It is a further confirmation of this view, that the *expression* of a countenance, which directly appeals to our ideational consciousness, is much more distinctly remembered by most persons than its *features*, the recognition of which is more dependent upon the recall of antecedent sensational states. What is true of the act of Recollection in this particular, is probably true also in great degree of *spontaneous* Memory; but perhaps we should admit that the renewal of past states of sensational consciousness may be effected by fresh sensory impressions which are closely allied to them; as would seem probable from the fact, that we find ourselves comparing the new sensations with the old, without having in the new case formed any distinct conception of the object by which the old were produced. And the fact has been already noticed (§ 591), that sensorial impressions have been not unfrequently reproduced, with which it did not seem likely that ideas had ever been connected.

remembered, although the individual cannot himself retrace them as having ever before been present to his consciousness; they being yet proved to have been so at some long antecedent period.* The instrumentality of the Cerebrum in this mental operation is strongly indicated by the fact, that disease or injury of that organ may destroy the Memory generally, or may affect it in various remarkable modes. Thus we not unfrequently meet with cases, in which the brain has been weakened by attacks of epilepsy or apoplexy, in such a manner as to prevent the reception of any *new* impressions; so that the patient does not remember anything that passes from day to day; whilst the impressions of events which happened *long before* the commencement of his malady, recur with greater vividness than ever. On the other hand, the memory of the long-since-past is sometimes entirely destroyed; whilst that of events which have happened subsequently to the malady, is but little weakened. The memory of particular classes of ideas is frequently destroyed; that of a certain language, or some branch of science, for example. The loss of the memory of words is another very curious form of this disorder, which not unfrequently presents itself: the patient understands perfectly well what is said, but is not able to reply in any other terms than *yes* or *no* —not from any paralysis of the muscles of articulation, but from his incapability of expressing the ideas in language. Sometimes the memory of a particular class of words only, such as nouns or verbs, is destroyed; or it may be impaired merely, so that the patient mistakes the proper terms, and speaks a most curious jargon. So, again, a person may remember the letters of which a word is composed, and may be able to *spell* his wants, though he cannot speak the *word* itself, asking for *bread* (for example) by the separate letters b, r, e, a, d. A very curious affection of the memory is that in which the *sound* of spoken words does not convey any idea to the mind; yet the individual may recognize in a written or printed list of words, those which have been used by the speaker, the *sight* of them enabling him to understand their meaning. Conversely, the sound of the word may be remembered, and the idea it conveys fully appreciated; but the visual memory of its written form may be altogether lost, although the component letters may be recognized. For this class of phenomena, in which there is rather a severance of the associative connections that have been formed between distinct states of consciousness, than an actual annihilation of the impression left by any of the latter, the term 'dislocation of memory' has been proposed by Sir H. Holland,† but, as he justly remarks, "no single term can express the various effects of accident, disease, or decay, upon this faculty, so strangely partial in their aspect, and so abrupt in the changes they undergo, that the attempt to classify them is almost as vain as the research into their cause." It is, perhaps, in the sudden changes produced by blows or falls, that we have the most extraordinary examples of this kind of disturbance; and it is scarcely less extraordinary, that

* A remarkable instance is mentioned by a writer (Miss H. Martineau?) in "Household Words," vol. ix. p. 206, of a congenital Idiot who had lost his mother when under two years old, and who could not have subsequently been made cognizant of anything relating to her; and who yet, when dying at the age of thirty, "suddenly turned his head, looked bright and sensible, and exclaimed in a tone never heard from him before, 'Oh my mother! how beautiful!' and sunk round again—dead."

† See his "Chapters on Mental Physiology," p. 146.

there should sometimes be a no less sudden recovery of the lost power, which we can scarcely do wrong in attributing to the return of the Cerebral organization to that previous condition of activity from which it had been perverted.

643. When we take all these phenomena into consideration, we can scarcely resist the conclusion that every act of ideational consciousness produces a certain modification in the nutrition of the Cerebrum; that the new mode of nutrition is continued according to the laws of Assimilation already adverted-to; and that thus the Cerebrum *forms itself* in accordance with the use that is made of it. And this unconscious storing-up of impressions, which can only be brought before the consciousness (under ordinary circumstances at least) by the connecting link of associations, affords a powerful argument for the doctrine which has already been frequently referred-to as probable,—that the Cerebrum is not itself a centre of consciousness, but that we only become conscious of *its* states, in the same manner as we do of those of the Retina and of other surfaces for the reception of external impressions, by means of the communication of the changes which take place in it to the Sensorium.

644. Although the term Memory is very commonly used to designate the *intentional* recall of past states of consciousness, as well as their 'spontaneous' or 'automatic' recurrence, yet it is properly restricted to the latter operation; the term *Recollection* being that which is appropriate to the former, whose peculiarity consists in the exertion of the Will to bring *that* before the consciousness, which does not spontaneously present itself to it. As this process affords a typical example of the mode in which the Will acts in directing the current of thought, we shall examine it a little more minutely.—In the first place it may be positively affirmed, that we cannot call-up any idea by simply *willing* it, for it is a necessary condition of an act of will, that there should be in the mind an idea of *what* is willed; and if the idea of the thing willed be already in the mind, it is obviously impossible to use the will to bring it there. But every one is conscious of the state of mind in which he *tries to remember* something which is not at the time present to his consciousness; and the question is, *how* he proceeds to bring the idea before it. The process really consists in the fixation of the attention upon one or more of the ideas already present to the mind, which may directly recall, by suggestion, that which is desiderated; the very act of thus *attending to* a particular idea, serving not only to intensify the idea itself, but also to strengthen the associations by which it is connected with others. There are certain ideas so familiar to us, that they seem necessarily to recur upon the slightest prompting of suggestion; yet even with regard to these, the voluntary recollection at any particular time involves the process just described. Thus if a man be asked his name, he usually finds no difficulty in giving the proper answer, because it only requires that his attention should be directed to the idea involved in the words 'my name,' to suggest the words of which that name may consist. But if the individual should be in that state of 'absence of mind,' which really consists in the fixation of the attention upon some internal train of thought, he may not be able on the sudden to transfer his attention to the new idea that is forced upon

his consciousness *ab externo;* and may thus hesitate and bungle, before he is able to answer the question with positiveness. So, again, it sometimes happens in old age, that men fail to recollect their own names, or the names of persons most familiar to them, in consequence of the weakening of the bond of direct association; and they then only recall it by the operation to be presently described. And there are states of mind, in which the power of voluntarily directing the thoughts is for a time suspended, and in which the individual cannot make the slightest effort to recall the most familiar fact, especially if possessed with the conviction that such effort is impossible (§ 672).

645. But supposing the mind to be in full possession of its ordinary powers, and the desiderated idea to be one which does not at once recur on the direction of the attention to some idea already in the mind; we then apply the same process to other ideas which successively come before our consciousness, selecting those which we recognize as most likely to suggest that which we require, and following-out one train of thought after another, in the directions which we deem most productive, until we either succeed in finding the idea of which we are in search, or give-up the pursuit as not worth further trouble. Thus a man who is making-up his accounts, and finds that he has expended a sum in a mode which he cannot recollect, sets himself to remember what business he has done, where he has recently been, what shops he may have entered, and so on. Or when a man meets another whom he recognizes as an acquaintance without remembering his name, he runs-over a number of names (one being suggested by another, when the attention is given to them), in hopes that some one of these may prove to be the one, which, when brought to his mind, is recognized as that of the object then before his consciousness; or he thinks of the place in which he may have previously seen him, this being recalled by fixing the attention on the association suggested by the sight of his face and figure, or by the sound of his voice, or by his personality altogether; or he endeavours to retrace the time which has elapsed since he last met with him, the persons amongst whom he then was, or the actions in which he was engaged, that some one or other of these various associations may suggest the desiderated name.

646. Upon the various Ideational states thus reproduced before the Mental consciousness, and sequentially connected in 'trains of thought' by the operation of Suggestion, all acts of *Reasoning* are founded. These consist, for the most part, in the aggregation and collocation of ideas, the decomposition of complex ideas into more simple ones, and the combination of simple ideas into general expressions; in which processes are exercised the faculty of *Comparison*, by which the relations and connections of ideas are perceived,—that of *Abstraction*, by which we mentally isolate from the rest any particular quality of the object of our thought,—and that of *Generalization*, by which we recognize the common properties we have abstracted, as composing a distinct notion, that of some *genus* in which the objects are comprehended. These operations, when carefully analyzed, seem capable of reduction to this one expression,—namely, the fixation of our Attention on some particular *classes of ideas*, from among those which Suggestion brings before our consciousness; and this fixation may result, as already shown, either from the peculiar

attractiveness which these classes of ideas have for us (the constitution of individual minds varying greatly in this respect), or on the determination of our own Will.—There is strong reason to believe that these processes may be performed *automatically* to a very considerable extent, without any other than a permissive act of Will. It is clearly by such automatic action that the before-mentioned 'fundamental axioms' or 'secondary intuitions' (§ 614) are evolved; and there is not one of the operations above described, which may not be performed quite involuntarily, especially by an individual who is naturally disposed to it. Thus to some persons, the tendency to *compare* any new object of consciousness with objects that have been previously before the mind, is so strong as to be almost irresistible; and this, or any other original tendency, is strengthened by the habit of acting in conformity with it. So, again, the tendency to *abstract* is equally strong in the minds of others, who instinctively seek to separate what is fundamental and essential in the properties of objects, from what is superficial and accidental; and their attention being most attracted by the former, they readily recognize the same characters elsewhere, and are thus as prone to combine and generalize, as others are to analyse and distinguish.

647. It is only, in fact, when we *intentionally* divert the current of thought from the direction in which it was previously running,—when we *determine* to put our minds in operation in some particular manner,—and make a *choice of means* adapted to our end (as in the act of Recollection already described) by purposely fixing our attention upon one class of objects and excluding others,—that we can be said to use the Will in our Intellectual processes; and this exercise of it is shown, by the analysis of our own consciousness, to be much rarer than is commonly supposed. Thus we may imagine a man sitting-down at a fixed hour every day, to write a treatise upon a subject which he has previously thought-out; after that first effort of Will by which his determination was made, the daily continuance of his task becomes so habitual to him, that no fresh exertion of it is required to bring him to his desk; and unless he feel unfit for his work, or some other object of interest tempt him away from it, so that he is called-upon to decide between contending motives, his Will cannot be fairly said to be brought into exercise. It may need, perhaps, some voluntary fixation of his attention upon the topics upon which he had been engaged when he last dropped the thread, to enable him to recover it, so as to commence his new labours in continuity with the preceding; but when once his mind is fairly engrossed with the subject, this developes itself before his consciousness according to his previous habits of mental action; ideas follow one another in rapid and continuous succession, clothe themselves in words, and prompt the movements by which those words are expressed in writing; and this automatic action may continue uninterruptedly for hours, without any tendency of the mind to wander from its subject, the Will being only called into play when the feeling of fatigue or the distraction of other objects renders it difficult to keep the attention fixed upon that which has previously held it by its own attractive power.—The converse of this condition is experienced, when some powerful interest tends to draw-off the attention elsewhere, and the thoughts are found to wander continually from the subject in hand; or when, from the undue pro-

traction of mental exertion, the state of the brain is such, that the thoughts no longer develope themselves consecutively in the mind, nor shape themselves into appropriate forms of expression. In either of these cases, the intellectual powers can only be kept in action upon the pre-determined subject, by a strong effort of the Will: of this effort we are conscious at the time, and feel that we need to put-forth even a greater power than that which would be required to generate a large amount of physical force through the muscular system; and we subsequently experience the results of it, in the feeling of excessive fatigue which always follows any such exertion.

648. The faculty of *Imagination* is in some respects opposed in its character to that of Reason; being chiefly concerned about fictitious objects, instead of real ones. Still, it is in a great degree an exercise of the same powers, though in a different manner (§ 638). Thus it is partly concerned in framing new combinations of ideas relating to external objects and is hence an extended exercise of Conception; placing us, in idea, in scenes, circumstances, and relations, in which actual experience never found us; and thus giving rise to a new set of objects of thought. In fact, every Conception of that which has not been itself an object of perception, may, strictly speaking, be regarded as the result of the exercise of Imagination. Now the new Conceptions or mental creations thus formed, take their character, in great degree from the Æsthetic and Emotional tendencies of the mind; so that the previous development of these affections will influence, not merely the selection of the objects, but the mode in which they are thus idealized. In the higher efforts of the Imagination, the mind is not so much concerned with the class of sensational ideas, as with those of the intellectual character; and the collocation, analysis, and comparison of these, by which new forms and combinations are suggested to the mind, involve the exercise of the same powers as those concerned in acts of Reasoning; but they are exercised in a different way. Whilst the Imagination thus depends upon the Intellectual powers for all its higher operations, the understanding may be said to be equally indebted to the imagination; for the ideal combinations, which are the results of the action of the latter, do not merely engage the attention of the Artist, who aims to develope them in material forms, but are the great sources of the improvement of the knowledge and happiness possessed by our race,—operating alike in the common affairs of life, by suggesting those pictures of the future which are ever before our eyes, and are our animating springs of action, with their visions of enjoyment never perhaps to be fully realized, and their prospects of anticipated evil that often prove to be an exaggeration of the reality,—prompting the investigations of Science, that are gradually unfolding the sublime plan on which the Universe is governed,—and leading to a continual aspiration after those higher forms of Moral and Intellectual beauty, which are inseparably connected with purity and love.

649. When the limitation which attaches to the exercise of Volition,—namely, its incapacity to *originate* mental activity of any kind (§ 628),—is kept in view, it becomes at once apparent that the power of the Will over the Imagination must be greatly inferior to that which it may exert over the Reasoning processes. For all that it can do is to give the Imaginative faculty fair play, by withdrawing all influences that would

tend to distract it, and by bringing-together those external conditions which are found (in the case of each individual) to be most favourable to its exercise, it may help, too, by selecting from among the ideas or feelings already before the consciousness, those which are felt to be most appropriate in themselves, or most likely to be fertile in serviceable suggestions; and thus the faculty may be directed and invigorated, cultivated and chastened, although its *productiveness* depends essentially on its own inherent fertility and on the energy of its automatic action.

650. Two striking instances may be adduced, of men distinguished, the one for Intellectual, the other for Artistic ability; in both of whom the mental action which evolved the result, seems to have been almost entirely of an automatic character.—All accounts of Coleridge's habits of thought, as manifested in his conversation (which was a sort of *thinking aloud*) agree in showing that his train of mental operations, once started, went on *of itself*, sometimes for a long distance in the original direction, sometimes with a divergence into some other track, according to the consecutive suggestions of his own mind, or to new suggestions introduced into it from without. His whole course of life was one continued proof of the weakness of his Will; for, with numerous gigantic projects continually in his mind, he could never bring himself even seriously to attempt to execute any one of them; and his utter deficiency in self control rendered it necessary for his welfare that he should yield himself to the control of others. The composition of the poetical fragment "Kubla Khan" *in his sleep*, is a typical example of automatic mental action; and almost his whole life might be regarded, in consequence of the deficiency of that self-determining power which is the pre-eminent characteristic of every really great mind, as a sort of waking dream.* One of the most characteristic examples of his extraordinary deficiency of Will was displayed very early in his career; for when he had found a bookseller (Mr. Cottle) generous enough to promise him fifty guineas for poems which he recited to him, and might have received the whole sum immediately on delivering the Manuscript, he went-on, week after week, begging and borrowing for his daily needs, in the most humiliating manner, until he had drawn from his patron the whole of the promised purchase money, without supplying him with a line of that poetry which he had only to *write-down* to free himself from obligation. Yet there was probably no man of his day who surpassed Coleridge in the combination of the Reasoning powers of the Philosopher with the Imagination of the Poet and the Inspiration of the Seer, and there was perhaps not one of the last generation, who has left so strong an impress of himself in the subsequent course of thought of reflective minds engaged in the highest subjects of Human contemplation.—So, again, the whole artistic life of Mozart, from his infancy to his death, save in so far as the earlier part of it was directed by his father, may be cited as an example of the spontaneous or automatic development of musical ideas, which, under the guidance of his intuitive sense of harmony (§ 607), expressed themselves in appropriate language. When only four years old, he began to write music, which was found to be in strict accordance with the rules of composition, although he had received no instruction in these. And

* The most striking portraiture of Coleridge's habits of conversation, is to be found in Carlyle's "Life of John Sterling."

when engaged, during his after-life, in the production of those works which have rendered his name immortal, it was enough for him to fix his thoughts in the first instance upon the subject (the libretto of an opera, for example, or the words of a religious service), so as to give the requisite start and direction to his ideas, which then flowed onwards without any effort of his own; so that the whole of a Symphony or an Overture would develope itself in his mind, its separate instrumental parts taking (so to speak) their respective shapes, without any *intentional* elaboration. In fact, the only exercise of Will that seemed to be required on his part, consisted in the noting-down of the composition when complete; and this, under the temptations of social intercourse, and a dislike to anything like 'work,' he would sometimes postpone until the last moment. Thus it is well known that his overture to Don Giovanni was only written-out (although it must have been previously composed) during the night previous to its performance, which took place without any rehearsal. It is recorded of him, that being once asked by an inferior musician, how he set to work to compose a symphony, he replied—"If you once think of *how* you are to do it, you will never write anything worth hearing. *I* write because I cannot help it." Mozart, like Coleridge, was a man of extremely weak will; he could neither keep firm to a resolution, nor resist temptation; and when not under the guidance of his excellent wife, was the sport of almost every kind of impulse. But there was probably never a more remarkable example than his musical career presents, of the automatic operation of that *creative* power which specially constitutes Genius; and his life is altogether a most interesting study to the Psychologist, as well as to the Musician.*

651. On the other hand, in the life and literary career of Southey, we have a striking example of what a determined Will, acting under a strong sense of Duty, may do in utilizing and turning to the best account endowments of a comparatively mediocre order. Although few of his poems may retain a lasting celebrity, yet his prose writings will always be models of excellence in composition; and he had his powers under such complete command, that he never failed (save from physical incapacity) to execute those engagements which are too often made by men of genius "only to be broken," and never shrank from what he felt to be a task of disagreeable drudgery, when once he had undertaken it.

652. But not only is much of our highest Mental Activity thus to be regarded as the expression of the *automatic* action of the Cerebrum:—we seem justified in proceeding further, and in affirming that the Cerebrum may act upon impressions transmitted to it, and may elaborate results such as we might have attained by the purposive direction of our minds to the subject, *without any consciousness* on our own parts; so that we only become aware of the operation which has taken-place, when we compare the result, as it presents itself to our minds after it has been attained, with the materials submitted to the process. The ordinary experience of most persons will supply them with examples of this form of Cerebral activity. One of the simplest instances of it is to be found in a curious phenomenon, which, though most men are occasionally conscious of it, has been scarcely recognized by Metaphysical inquirers; namely, that when we have been trying to recollect some name, phrase, occurrence, &c.,

* See especially the "Life of Mozart" by Edward Holmes.

and, after vainly employing all the expedients we can think-of for bringing the desiderated idea to our minds, have abandoned the attempt as useless, it will often occur spontaneously a little while afterwards, suddenly flashing (as it were) before the consciousness; and this although the mind has been engrossed in the mean time by some entirely-different subject of contemplation, and cannot detect any link of association whereby the result has been obtained, notwithstanding that the whole train of thought which has passed through the mind in the interval may be most distinctly remembered.* Now it is difficult, if not impossible, to account for this fact upon any other supposition, than that a certain train of action has been set-going in the Cerebrum by the voluntary exertion which we at first made; and that this train continues in movement after our attention has been fixed upon some other object of thought, so that it goes-on to the evolution of its result, not only without any continued exertion on our own parts, but also without our consciousness of any continued activity.—Another familiar example of a like kind, is presented by the process by which we acquire a knowledge of the meaning of an author whose writings we are perusing. For, if the subject be one into which we readily enter, and if the writer's flow of thought be one which we easily follow, and his language be appropriate to express his ideas, we acquire the meaning of one *sentence* after another, without any conscious recognition of the meaning of each of its component *words*; and yet it is certain that a particular impression must have been made by each of these words upon the Cerebrum, before we can comprehend the notion which they were collectively intended to convey. It is only when the language is ill-chosen, or when we do not readily follow the author's train of thought, that we direct our attention to the signification of the individual words, and become conscious of their separate meaning. In like manner, an expert calculator will cast his eye rapidly from the bottom to the top of a column of figures, and will name the total, without any conscious appreciation of the value of each individual figure.

653. But in these instances, no higher act of mind is required, than the production of one complex idea out of an aggregate of simpler elements; there are cases, however, in which processes of a far more elaborate nature are carried-on, without necessarily affecting our consciousness. Most persons who attend to their own mental operations, are aware that when they have been occupied for some time about a particular subject, and have then transferred their attention to some other, the first, when they return to the consideration of it, may be found to present an aspect very different from that which it possessed before it was put aside; notwithstanding that the mind has since been so com-

* So frequently has this occurred within the Author's experience, that he is now in the habit of trusting to this method of recollection, where he has reason to feel sure that the desired idea is not far off, if the mind can only find its track—as when it relates to some occurrence (such as a payment of money) which is known to have taken place within a few days previously; for he has found himself much more certain of recovering it, by withdrawing his mind from the search when it is not speedily successful, and by giving himself up to the occupation appropriate to the time, than by inducing fatigue by continuous efforts. And this is not his own experience only, but that of many others. The fact has been noticed by Sir H. Holland ("Chapters on Mental Physiology," p. [illegible]), from whom he has learned that the above plan has been put into successful action by many to whom he has recommended it.

pletely engrossed with the second subject, as not to have been consciously directed towards the first in the interval. Now a part of this change may depend upon the altered condition of the mind itself, such as we experience when we take-up a subject in the morning with all the vigour which we derive from the refreshment of sleep, and find no difficulty in overcoming difficulties and in disentangling perplexities which checked our further progress the night before, when we were too weary to give more than a languid attention to the points to be made-out, and could use no exertion in the search for their solutions. But this by no means accounts for the *entirely-new development* which the subject is frequently found to have undergone, when we return to it after a considerable interval; a development which cannot be reasonably explained in any other mode, than by attributing it to the intermediate activity of the Cerebrum, which has in this instance automatically evolved the result without our consciousness. Strange as this phenomenon may at first sight appear, it is found, when carefully considered, to be in complete harmony with all that has been already affirmed, respecting the relation of the Cerebrum to the Sensorium, and the independent action of the former; and looking at all those automatic operations by which results are evolved without any intentional direction of the Mind to them, in the light of 'reflex actions' of the Cerebrum, there is no more difficulty in comprehending that such reflex actions may proceed without our knowledge, so as to evolve *intellectual products* when their results are transmitted to the Sensorium and are thus impressed on our consciousness, than there is in understanding that impressions may excite muscular movements through the 'reflex' power of the Spinal Cord, without the necessary intervention of Sensation. In both cases, the condition of this mode of independent operation, is that the *receptivity* of the Sensorium shall be suspended *quoad* the changes in question, either by its own functional inactivity, or through its temporary engrossment by other processes.—It is difficult to find an appropriate term for this class of operations. They can scarcely be designated as Reasoning Processes, since 'unconscious reasoning' is a contradiction in terms. The designation *Unconscious Cerebration* is perhaps less objectionable than any other. (See § 663.)

654. But it must not be left out of view, that *Emotional* states, or rather states which constitute emotions when we become conscious of them, may be developed by the same process; so that our feelings towards persons and objects may undergo most important changes, without our being in the least degree aware, until we have our attention directed to our own mental state, of the alteration which has taken-place in them. A very common but very characteristic example of this kind of action, is afforded by the powerful attachment which often grows-up between individuals of opposite sexes, without either being aware of the fact; the full strength of this attachment being only revealed to the consciousness of each, when circumstances threaten a separation, and when each becomes cognizant of the feelings entertained by the other. The existence of a mutual attachment, indeed, is often recognized by a by-stander (especially if the perceptions be sharpened by jealousy, which leads to an intuitive interpretation of many minute occurrences which would be without signification to an ordinary observer), before either of the parties has made the

discovery, whether as regards the individual *self*, or the beloved *object*: the Cerebral state, manifesting itself in action, although no distinct consciousness of that state has been attained, chiefly because, the whole attention being attracted by the present enjoyment, there is little disposition to Introspection.—The fact, indeed, is recognized in our ordinary language; for we continually speak of the 'feelings' which we unconsciously entertain towards another, and of our not becoming aware of them until some circumstances call them into activity. Here again, it would seem as if the material organ of these feelings tends to *form itself* in accordance with the impressions which are habitually made upon it; so that we are as completely unaware of the changes which may have taken place in it, as we are of those by which passing events are registered in our minds (§ 642), until some circumstance calls-forth the conscious manifestation, which is the 'reflex' of the new condition which the organ has acquired. And it may be desirable to recal the fact in this connection, that the Emotional state seems often to be determined by circumstances of which the individual has no distinct consciousness, and especially by the emotional states of those by whom he is surrounded (§ 609); a mode of influence which is exerted with peculiar potency on the minds of children, and which is a most important element in their Moral education.*

655. *Ideo-Motor Actions*.—Although it has been usual to designate by the term Voluntary, all those muscular movements which take place as the result of mental operations save when they are the expression of Emotional states, yet a careful analysis of the sources from which many of even our ordinary actions proceed, will show that the Will has no direct participation in producing them, and that they are, Psychologically speaking, the spontaneous manifestations of Ideational states excited to a certain measure of intensity, or, in Physiological language, the *reflex actions of the Cerebrum*. This mode of operation has been already shown (§§ 469, 470) not only to be fully conformable to the general plan of the activity of the Nervous System, but even to complete or fill-up a part of it which would otherwise be left void; and we shall find that it serves to account for a great number of phenomena which had not previously been included under any general category, and which, when thus combined and generalized, form a most interesting and remarkable group, well deserving of attentive study.—It is, of course, when the Intellect is in a state of exalted (though it may be aberrant) activity, but when the directing power of the Will is suspended or weakened, that we should expect to see the most remarkable manifestations of the reflex power of the Cerebrum; and such is the condition of the Somnambulist who *acts* his dreams (§ 693), and of the 'Biologized' subject who *acts* his reverie (§ 672). In each case, the mind is possessed by a succession of ideas, which may either be spontaneously evolved by its own operations, or may be directly suggested through the senses, or may be the products of the mental activity of the individual, exercised upon the promptings which it has received from without. In whatever mode the ideas have been brought before the consciousness, it is the essential characteristic of these states that

* See an admirable Discourse on 'Unconscious Influences,' by the Rev. Horace Bushnell, of Hartford (N. E.), published in the "Penny Pulpit," No. 1199.

the Mind is entirely given-up to that which may happen to be before it at the time, which consequently exerts an uncontrolled directing power over the actions, there being no antagonistic agency to keep it in check.

656. To this category, too, belong a variety of aberrant actions, bordering on Insanity, of which the history of mankind in all ages furnishes us with abundant examples; that which is common to all of them, being the entire possession of the ideational consciousness by some strongly-excited 'dominant idea,' the intensity of which blinds the common-sense and subjugates the will, so that it expresses itself in bodily action without the least restraint. The notion may, or may not, be in itself an absurd one. It may be confined to a single individual, or it may spread epidemically through a multitude. It may be one that interests the feelings, or it may be of a nature purely intellectual. The wild but transient vagaries of religious enthusiasm in all ages,—as shown in the Pythonic inspiration of the Delphic priestesses; the ecstatic revelations of Catholic and Protestant visionaries; the preaching epidemic among the Huguenots in France, and more recently in Lutheran Sweden; the strange performances of the 'Convulsionnaires' of St. Médard, which have been since almost paralleled at Methodist 'revivals' and 'camp-meetings,'—the Dancing Mania of the Middle Ages; the Tarentism of Southern Italy, the Tigretier of Abyssinia, and the Leaping-ague of Scotland in later times,*—together with that most recent, but not least remarkable specimen (the character of the individuals affected being taken into account), the Table-turning and Table-talking epidemic which spread through almost the whole civilized world in 1852-3;—are all, with many similar wonders, to be ranged under the same category. The 'dominant idea' not unfrequently declines in intensity, especially when it expends its force in action, and the mind spontaneously returns to its previous condition; and thus it is that we find these Epidemic Delusions passing-away of themselves, without any ostensible cause for their cessation. Sometimes, however, such an idea may continue to exert a dominant influence over the whole of life; and if the conduct which it dictates should pass the bounds of enthusiasm or eccentricity, we say that the individual is the subject of Monomania. The nature of this state will be more fully considered hereafter (§ 709).

657. The same view may be fairly applied, also, to all those actions performed by us in our ordinary course of life, which are rather the automatic expressions of the ideas which may be dominant in our minds at the time, than prompted by distinct volitional efforts (§ 647). Of this kind, the act of expressing the thoughts in language, whether by speech or writing, may be considered as a good example; for the attention may be so completely given-up to the choice of words and to the composition of the sentences, that the movements by which these words are uttered by the voice or traced on paper, no more partake of the truly volitional character, than do those of our limbs when we walk through the streets in a state of Abstraction. And it is a curious

* On the greater number of the foregoing subjects, much curious information will be found in Dr. Hecker's account of the 'Dancing Mania,' forming part of his Treatise "On the Epidemics of the Middle Ages," translated for the Sydenham Society by Dr Babington.

evidence of the influence of Ideas, rather than of the agency of the Will, in producing them, that, as our conceptions are a little in advance of our speech or writing, it occasionally happens that we mis-pronounce or mis-spell a word, by introducing into it a portion of some other whose turn is shortly to come, its place in the sentence which is in process of formation being a little further-on; or it may be that the whole of the anticipated word is substituted for the one which ought to have been expressed. Now it is obvious that there could be neither any consciously-formed intention of breaking the regular sequence, nor any volitional effort to do so, and the result is evidently due to the superior vividness with which the idea of the anticipated word is present to the mind, as compared with that of the word which the course of construction requires. It is the *dominant idea*, then, which determines the movement, the Will simply permitting it; and the more completely the Volitional power is directed to other objects, the more completely automatic are the actions of this class. They may, indeed, come to be performed even without the consciousness, or at least without the remembered consciousness, of the agent; as we see in the case of those who have the habit of 'thinking aloud,' and who are subsequently quite surprised on learning what they have uttered. The one-sided conversation of some persons, who are far more attentive to their own trains of thought, than they are to what may be expressed by others, and who are allowed to proceed with little or no interruption, is often a sort of 'thinking aloud.'*

658. Much attention has recently been given to a set of Involuntary movements, which, however diverse the circumstances under which they occur, all have their source in the same mental condition,—that of *expectant attention;* the whole Mind being possessed with the Idea that a certain action will take place, and being eagerly directed towards the indications of its occurrence. Such movements are well known to occur in the involuntary muscles connected with the Organic functions, which receive their nervous supply from the Sympathetic system; and they are among the means by which important modifications are produced in these functions through the direction of the mind to them. (See § 829).

659. But it is with the Involuntary movements produced by the same agency through the Cerebro-spinal system, in the muscles ordinarily accounted Voluntary, that we are at present especially concerned. This is a very curious subject of inquiry, and one on which adequate scrutiny has scarcely yet been bestowed; the phenomena which are referable to the principle of action here enunciated, having been very commonly explained by the agency of some other force. Thus, if a button or ring be suspended from the end of the finger or thumb, in such a position that, when slightly oscillating, it shall strike against a glass tumbler, it has been affirmed by many who have made the experiment, that the button continues to swing with great regularity, striking the glass at tolerably-regular intervals, until it has sounded the hour of the day, after which it ceases for a time to swing far enough to make another stroke. This certainly does come to pass, in many instances, without

* This was pre-eminently the case with Coleridge, whose whole life was little else than a waking dream, and whose usual talk was the outpouring of his dominant ideas. (See § 650.)

any intention on the part of the performer; who may be really doing all in his power to keep his hand perfectly stationary. Now it is impossible, by any voluntary effort, to keep the hand absolutely still, for any length of time, in the position required; an involuntary tremulousness is always observable in the suspended body; and if the *attention* be fixed upon the part, with the *expectation* that the vibrations will take a determinate direction, they are very likely to do so.* Their persistence in this direction, however, *only takes place so long as they are guided by the visual sensations;* a fact which at once points to the real spring of their performance. When the performer is impressed with the conviction that the hour *will* be thus indicated, the result is very likely to happen; and when it has once occurred, his confidence is sufficiently established to make its recurrence a matter of tolerable certainty. On the other hand, the experiment seldom succeeds with sceptical subjects, the expectant idea not having in them the requisite potency. That it is through the Mind that these movements are regulated, however involuntarily, appears evident from these two considerations; first, that if the performer be entirely ignorant of the hour, the strokes on the glass do not indicate its number, except by a casual coincidence; and second, that the division of the entire period of the earth's rotation into twenty-four hours, and the very nomenclature of these hours, being entirely arbitrary and conventional, cannot be imagined to operate in any other mode.† These phenomena, in which no hypothetical 'odylic' or other concealed agency can be reasonably supposed to operate, are here alluded to only for the sake of illustrating those next to be described, which have been imagined to prove the existence of a new force in Nature.

660. So, again, if "a fragment of anything, of any shape," be suspended from the end of the fore-finger or thumb, and the attention be intently fixed upon it, regular oscillations will be frequently seen to take place in it; and if changes of various kinds be made in the conditions of the experiment, by placing bodies of different sorts beneath the pendulum, or by the contact of different persons or things with the person of the suspender, corresponding changes in the direction of the movements will very commonly follow.‡ Now this will occur, notwithstanding the strong desire of the experimenter to maintain a complete immobility in the suspending finger; but it is very easily proved that the movements are guided by his visual sensations, and that the impulse to them is entirely derived from his expectation of a given result. For, if he close his eyes, or withdraw them from the vibrating body, its oscillations (as in the previous case) immediately lose their constancy; manifestly proving that the influence which directs

* This was long since pointed out by M. Chevreul, who investigated the subject in a truly philosophic spirit. See his letter to M. Ampère, in the "Revue des Deux Mondes," May, 1833; and his recent treatise "De la Baguette Divinatoire, du Pendule dit Explorateur, et des Tables Tournantes," Paris, 1854.

† For instance, the button which strikes *eleven* at night in London, should strike *twenty-three* in Rome, where the cycle of hours is continued through the whole twenty four hours; and if an Act of Parliament were to introduce the Italian horary arrangement into this country, all the swinging buttons in her Majesty's dominions would have to add twelve to their number of post-meridian strokes; all which would doubtless come to pass, if the experimenters' faith in the result were sufficiently strong.

‡ See Dr. H. Mayo on "The Truths contained in Popular Superstitions," 3rd edition, Letter xii.

them acts through his consciousness. And, again, if he be ignorant of the change which is made in the conditions of the experiment, and should expect or guess something different from that which really exists, the movement will be in accordance with *his idea*, not with the reality.* —Thus, then, we have here a most distinct proof that a state of mind exists, which is neither volitional nor emotional, but which consists in the complete engrossment of the attention by a fixed Idea, whereby definite muscular movements are produced, in spite of a determined exertion of the Will. The Will is concerned, however, in the induction of the mental state in question, by the fixation of the attention on the oscillating body; and it is only in those individuals who possess the power of voluntary abstraction (§ 668) to a considerable extent, that the experiment is likely to succeed. It is scarcely necessary to add that as *faith* in its results is essential to their production, those who are acquainted with the mode in which they are really brought-about, are not likely to be good subjects for it.

661. It is doubtless on the very same physiological principle, that we are to explain the mysterious phenomena of the 'Divining Rod,' which have been accepted as true, or rejected as altogether fabulous, according to the previous habits of thought of those who have given their attention to the subject. Now, that the end of a hazel-fork, whose limbs are grasped firmly in the hands of a person whose good faith can scarcely be doubted, frequently points upwards or downwards without any intentional direction on his part, and often thus moves when there is metal or water beneath the surface of the ground at or near the spot, is a fact which is vouched-for by such testimony, that we have scarcely a right to reject it; and when we come to examine into the conditions of the occurrence, we shall find that they are such as justify us in attributing it to a state of *expectant attention*, which (as we have seen) is fully competent to induce muscular movement. For in the first place, as not above one individual in forty, even in the localities where the virtues of the divining-rod are still held as an article of faith, is found to succeed in the performance of this experiment, it is obvious that the agency, whatever be its nature, which produces the deflection, must operate by affecting the holder of the rod, and not by attracting or repelling the rod itself. And when experiments are carefully made with the view of determining

* A most remarkable and convincing exemplification of this fact, is afforded by Dr. Henry Madden's experiments with Mr. Rutter's "Magnet meter," at Brighton, recorded in the "Lancet" for Nov. 15, 1851. Dr. Madden had satisfied himself, in the first instance, that the vibrations of the suspended body were affected by the contact, with his other hand, of homœopathic globules, whose differences of composition were indicated by corresponding changes in the direction of the oscillations. But having been led to examine the question, and to apply that test which he ought to have applied at first,—namely, to have various globules put into his hand, without his being himself aware of their composition,—he found that the results entirely lost their previous constancy, which was thus evidently due to his expectation of a particular movement in each case. It is a manifestation of the very imperfect analysis which is commonly made of such phenomena, that, from the moment when they are found referrible to a physiological principle, instead of demonstrating (as they were at first supposed to do) the existence of a new force, they seem to lose all their interest for those who had previously watched them with eagerness, and to be set down as illusory, or as the product of the 'imagination,' notwithstanding that they are as *real* in the one case as in the other, and are in no degree less curious and interesting when considered under the former aspect, than when viewed in the latter.

the nature of this agency, they are found to indicate most clearly that the state of 'expectant attention,' induced by the anticipation of certain results, is fully competent to produce them. For the mere act of holding the rod for some time in the required position, and of attending to its indications, is sufficient to produce a tendency to spasmodic contraction in the grasping muscles, notwithstanding a strong effort of the will to the contrary; and when, by such contractions, the limbs of the fork are made to approximate-towards or to separate-from each other, the point of the fork will be caused to move either upwards or downwards, according to the position in which it is held. If, when the muscles have this tendency to contract, occasioned by their continued restraint in one position, the mind be possessed with the expectation that a certain movement will ensue, that movement will actually take-place, even though a strong effort may be made by the Will to prevent any change in the condition of the muscles. And a sufficient ground for such expectation exists, on the part of those who are possessed with the idea of the peculiar powers of the divining-rod, in the belief, or even in the surmise, that water or metal may lie beneath particular points of the surface over which they pass.* —The same instrument appears to have been used, even from a

* This was admitted even by Dr H. Mayo, notwithstanding his belief in the existence of an 'Od-force,' governing the movements of the divining-rod. For he found in the course of his experiments, that when his 'diviner' knew which way he expected the fork to move, it invariably answered his expectations, but when he had the man blindfolded, the results were uncertain and contradictory. Hence he became certain that several of those in whose hands the divining rod moves, set it in motion, and direct its motion (however unintentionally and unconsciously) by the pressure of their fingers, and by carrying their hands nearer-to or apart from each other (see his Letters "On the Truths contained in Popular Superstitions," Letter i.)—The following statement of the results obtained by a very intelligent friend of the Author, who took-up the inquiry some years ago, with a strong prepossession (derived from the assurances of men of high scientific note) in favour of the reality of the supposed influence, but yet with a desire to investigate the whole matter carefully and philosophically for himself, will serve as a complete illustration of the doctrine enunciated above. Having duly provided himself with a hazel fork, he set out upon a survey of the neighbourhood in which he happened to be staying on a visit, this district was one known to be traversed by mineral veins, with the direction of some of which he was acquainted. With his 'divining rod' in his hand, and with his attention closely fixed upon his instrument of research, he walked-forth upon his experimental tour, and it was not long before, to his great satisfaction, he observed the point of the fork to be in motion, at the very spot where he knew that he was crossing a metallic lode. For many less cautious investigators, this would have been enough, but it served only to satisfy this gentleman that he was a favourable subject for the trial, and to stimulate him to further inquiry. Proceeding in his walk, and still holding his fork *secundum artem*, he frequently noticed its point in motion, and made a record of the localities in which this occurred. He repeated these trials on several consecutive days, until he had pretty thoroughly examined the neighbourhood, going over some parts of it several times. When he came to compare and analyse the results, he found that there was by no means a satisfactory accordance amongst them; for there were many spots over which the rod had moved on one occasion, at which it had been obstinately stationary on others, and *vice versâ*; so that the constancy of a physical agency seemed altogether wanting. Further, he found that whilst some of the spots over which the rod had moved, were those known to be traversed by mineral veins, there were many others in which its indications had been no less positive, but in which those familiar with the mining geology of the neighbourhood were well assured that no veins existed. On the other hand, the rod had remained motionless at many points where it *ought* to have moved, if its direction had been affected by any kind of terrestrial emanation. These facts led the experimenter to a strong suspicion that the cause existed in himself alone, and carrying out his experiments still further, he ascertained that he could not hold the fork in his hand for many minutes consecutively, concentrating his attention fixedly upon it, without an alteration in the

very early period, by those who were supposed to possess 'a gift of divination,' for the purpose of giving replies to questions by its movements, precisely after the fashion of the 'talking tables' of our own day; the hands of the operators (where they really believed in their power and were not impostors) being automatically impelled to execute the appropriate movements of the rod, by their idea of what the answer should be.*

602. No difficulty can be felt by any one who has been led by the preceding considerations to recognize the principle of 'Ideo-Motor actions,' in applying this principle to the phenomena of 'Table-turning' and 'Table-talking;' which, when rightly analysed, prove to be among the very best examples of the reflex operation of the Cerebrum that are exhibited by individuals whose state of mind can scarcely be considered as abnormal. The *facts*, when stripped of the investment of the marvellous with which they have too commonly been clothed, are simply as follows:—A number of individuals seat themselves round a table, on which they place their hands, with the *idea* impressed on their minds that the table will move in a rotatory direction, the direction of the movement, to the right or to the left, being generally arranged at the commencement of the experiment. The party sits, often for a considerable time, in a state of expectation, with the whole attention fixed upon the table, and looking eagerly for the first sign of the anticipated movement. Generally one or two slight changes in its place herald the approaching revolution; these tend still more to excite the eager attention of the performers, and then the actual 'turning' begins. If the parties retain their seats, the revolution only continues as far as the length of their arms will allow; but not unfrequently they all rise, feeling themselves obliged (as they assert) to *follow* the table; and from a walk, their pace may be accelerated to a run, until the table actually spins-round so fast that they can no longer keep-up with it. All this is done, not merely without the least consciousness on the part of the performers that they are exercising any force of their own, but for the most part under the full conviction that they are not.—Now the *rationale* of these and other phenomena of a like kind, is simply as follows. The continued concentration of the attention upon a certain Idea gives it a 'dominant power,' not only over the mind, but over the body; and the muscles become the involuntary instruments whereby it is carried into operation. In this case, too, as in that of the divining-rod, the movement is favoured by the state of muscular tension, which ensues when the hands have been kept for some time in a fixed position. And it is by the continued influence of the 'dominant idea,' that the performers are impelled to follow (as they believe) the revolution of the table, which they really maintain by their continued propulsion. However conscientiously they may believe

direction of its point, in consequence of an involuntary though almost imperceptible movement of his hands; so that in the greater number of instances in which he observed the motion, the phenomenon was clearly attributable to this cause, and it was a matter of accident whether the movement took-place over a mineral vein, or over a blank space. And further, he ascertained on a comparison of his results, that the movement took place most frequently where he knew or suspected the existence of mineral veins, than in other situations; and thus he came, without any knowledge of the theory of expectant attention, to the practical conclusion that the actions of his nerves and muscles were in great degree regulated by the ideas which possessed his mind.

* See Chevreul, Op. cit., première partie.

that the attraction of the table carries them along with it, instead of an impulse which originates in themselves pushing along the table, yet no one feels the least difficulty in withdrawing his hand, if he really *wills* to do so. But it is the characteristic of the state of mind from which ideo-motor actions proceed, that the volitional power is for the time in abeyance; the whole mental power being absorbed (as it were) in the high state of tension to which the ideational consciousness has been wrought-up.—To this rationale, all the results of the variations that have been from time to time introduced into the experiment, are perfectly conformable; it having been always found, that when any method was employed under the conviction that the process would be favoured by it (as when, during the reign of the electrical hypothesis, the feet of the table were insulated, or a continuous circuit was made by the hands of the performers), the expectation thus excited brought-about the result at an earlier period than usual.*

663. The application of the same principle to the ordinary phenomena of 'Table-talking,' is so obvious as to need no lengthened exposition. There can be no reasonable doubt that these phenomena have been manifested in a large number of instances, through the agency of individuals who would not wilfully be parties to deception of any kind; and that the movements which they involuntarily gave to the tables, were the expressions of the ideas with which their own minds were possessed, as to what the answers should be to the questions propounded.† It is asserted, however, that the 'talking-tables' often give true answers to questions proposed to them as to matters of fact, though none of the parties present may have any knowledge of what the answers should be; but this, if it be really so, is not only far from being opposed to the Physiological doctrines here advanced, but affords a curious illustration and extension of them. For, as there is no doubt that impressions once made upon our consciousness, though subsequently entirely lost to it, may direct our trains of thought in Delirium and Dreaming, or may even, as in Somnambulism, govern our actions, so does it seem quite reasonable to attribute the muscular movements by which the table is made to answer, to impressions left by past ideas upon the Cerebrum, on which it reacts, by an operation analogous to the 'unconscious cerebration' already described (§ 653), so as to work-out results through the muscular system, of whose source

* The demonstration that the table really is moved by the hands placed upon it, notwithstanding the positive conviction of the performers to the contrary, was first afforded by the very ingenious 'indicator' devised by Prof. Faraday, which showed that lateral pressure is *always* exercised, however unconsciously, before the movement commences, and that if, by keeping their eyes upon the index, the performers check the first tendency to exert such pressure, the table never gives the least sign of movement. Prof. Faraday did not, in his well-known Letter on this subject ("Athenæum," July 2, 1853), offer any *physiological* rationale of this unconscious muscular action; but referred for *it* to "the Discourse delivered by Dr. Carpenter at the Royal Institution, March 12, 1852, 'On the influence of Suggestion in modifying and directing Muscular Movement independently of Volition,'" in which the doctrine of Ideo-motor action had been for the first time publicly enunciated.

† This must be perfectly clear to those who will read with candour the various publications of their experience with 'talking tables,' put forth by the Revds. N. S. Godfrey, E. Gillson, R. W. Dibdin, and other clergymen, who had adopted the idea that they communicated through these means with Evil Spirits, or even with Satan himself. A more detailed analysis of this and other kindred subjects than the present work affords space for, will be found in the "Quarterly Review," Sept., 1853.

within himself the operator is as ignorant, as he is of his exercise of nerve-force in calling the muscles into contraction.* The truth of this view has been tested by experiments so varied as to exclude all possibility of influence from such 'latent ideas,' and it has been then found that the table could reveal nothing whatever.

664. To this same category are doubtless to be referred a large number of those actions of Mesmeric 'subjects,' which have been considered by some as most unequivocal indications of the existence of an agent *sui generis*, whilst by others they have been regarded as the results of intentional deception. Many of them are of a kind which the Will cannot feign, being violent convulsive movements, such as no voluntary effort could produce; but the Mesmeric 'subject' being previously possessed with the expectation that certain results will follow certain actions (as, for instance, that convulsive movements will be brought on by touching a piece of mesmerized metal), and the whole nervous power being concentrated, as it were, upon the performance, the movements follow when the subject *believes* the conditions to have been fulfilled, whether they *have* been, or not. These facts were most completely established by the Commission appointed to investigate the pretensions of Mesmer himself; and whilst they demonstrate the unreality of the supposed mesmeric influence (so far, at least, as this class of phenomena is concerned), they also prove the position here contended-for, namely, the sufficiency of the state of *expectant attention*, in those whose minds are completely possessed by it, to produce effects of the same nature with those which are induced in Hysterical subjects by emotional excitement. (See § 656).

665. *Determining Power of Volition.*—We have now, in the last place to enquire into the mode in which *Volition* operates in determining the course of Thought and the regulation of the Conduct;—a problem of extreme difficulty, the entire solution of which may not be within the limited sphere of Man's present capacity. The chief subject of embarrassment, however, is rather the nature and source of the Will itself than the conditions of its operation; for whilst a careful analysis of our own consciousness throws much light on the latter, the scientific investigation of the former has seemed to lead to results which are inconsistent with our intuitive conviction of freedom, as well as with our scarcely less intuitive notion of moral responsibility. Dismissing the former question

* The following is a remarkable example of this kind of action, which is detailed in the Rev. R. W. Dibdin's Lecture on Table-turning. A gentleman who was at that time a believer in the 'spiritual' agency of his table, supposed himself to be in communication with Edward Young, the poet. The spirit having been desired to prove his identity by citing a line of his poetry, the table rapped out "Man was not made to question, but adore." Being asked whether the line was in the 'Night Thoughts,' the spirit replied through the table "No." "Where is it then?" The reply was "Job." Not being familiar with Young's Poems, the questioner did not know what this meant; but the next day he bought a copy of the book, and at the end of the Night Thoughts he found a Paraphrase on Job, the last line of which is that just cited. Of course he was very much astonished that this should have been communicated by the table; but some time afterwards, he found that he had had the book in his house all the time, and that he had read it before; so that the remarkable line with which the Paraphrase of Job closes, had in all probability made an enduring impression, which, being called into activity by an appropriate suggestion, exercised the same effect upon his muscular movements, as if the remembrance of it had been actually present to his consciousness.

therefore, as one which requires a much more laboured discussion than could here be appropriately bestowed upon it, we may apply ourselves to the consideration of the mode in which Volition acts (1.) upon the Corporeal organism, and (2.) upon our Psychical nature.

666. It is a fact of universal experience, that, although certain states of Mind have a remarkable influence on the Organic functions, no change in their usual course can be determined by the direct influence of the Will.* The only sensible effect which the strongest effort of Volition can produce on the bodily frame, is the excitation of *muscular contraction*. Now if we examine into the *cause* of a Volitional† movement, we find it to lie, as in other instances, in a certain combination of *material conditions* with *dynamical agency* (§ 585). The aggregate of the material conditions is a state of integrity of the Muscular and Nervous apparatus through which the Will operates; the dynamical agency is the *effort* which we are conscious of putting-forth, and which we feel to be *the power* by which the work is done, the degree of volitional exertion required being strictly proportional to the amount of *resistance* to be overcome, and being followed by a corresponding sense of *fatigue*, which is the indication of the expenditure of force. As already pointed-out (§ 625), it is an essential condition of every Volitional action, that a distinct idea should exist of the object to be attained, and that there should be also a belief in the possibility of attaining it by the means employed; and further, the amount of power which can be put-forth on any occasion, is dependent, *cæteris paribus*, upon the degree in which the attention is concentrated upon the effort, and the mind withdrawn from the contemplation of other objects. Hence it is (as was there shown), that Emotional excitement may either intensify or may paralyse the Volitional power, according as it determines or interferes-with the special direction of the mental energy to the object with which it is connected. But the same influence is capable of being exerted by the simple dominance of *ideas*, in certain states of mind in which the directing power of the Will over the current of thought is altogether suspended, without the destruction of the capacity for voluntary exertion of the nervo-muscular apparatus. Thus the Author has seen a man remarkable for the poverty of his muscular development, who shrank from the least exertion in his ordinary state, lift a 28-lb. weight upon his little finger alone, and swing it round his head with the greatest facility, when in that state of artificial somnambulism termed Hypnotism by Mr. Braid (§ 695); his extraordinary command of muscular power in this condition, being simply due to the complete concentration of his mental energy upon the one object, and to the dominance of the idea (with which his mind was possessed by

* "Which of you, by taking thought, can add one cubit to his stature?" "Thou canst not make one hair white or black."

† The term *volitional* was some years since suggested by Dr. Symonds, in an excellent essay on the 'Connection between Mind and Muscle,' published in the "West of England Journal," 1835, as expressing more emphatically than *voluntary* the characters of an action proceeding from a distinct choice of the object, and from a determinate effort to attain it. The word *voluntary* may perhaps be applied to that wider class of actions, in which there is no very distinct choice or conscious effort, but in which the movement flows as it were spontaneously from the antecedent mental state; the consciousness, however, being fully awake to its performance, and the will being brought to bear determinately upon it, whenever an opposing motive tends to check the process or to alter its direction. See § 647.

the confident assurances of Mr. Braid) that he *could* attain it with the greatest facility,—that idea not being negatived by his ordinary experience, for reasons to be presently stated (§ 670). On the other hand, the same individual (whilst in the hypnotic state) declared himself altogether unable to raise a handkerchief from the table, after many apparently strenuous efforts; his mind having been previously possessed by the assurance, that its weight was too great for him to move.* In that curious state of artificial Reverie, which has recently attracted much attention under the inappropriate name of 'Electro-Biology' (§ 672), precisely the same phenomena may be observed; the subjects of it being prevented from performing the commonest voluntary movements, by the assurance that they *cannot* execute them, which assurance takes full possession of their minds, in virtue of their want of power to bring their ordinary experience to bear upon the idea thus introduced; whilst they may be compelled, by the dominance of ideas introduced in like manner by external suggestion, to perform actions, which, if not physically impossible to them in their ordinary state, they could not be induced to execute by any conceivable motives.

667. These facts are not so far removed from our ordinary experience as might at first sight appear. For it must be within the knowledge of every one, that, when *first* attempting to perform some new kind of action, the power we feel capable of exerting depends in great measure upon the degree of our assurance of success. Of this we have a good example in the process of learning to swim; which is greatly facilitated, as Dr. Franklin pointed-out, by our first taking means to satisfy ourselves of the buoyancy of our bodies in the water, by attempting to pick up an object from the bottom. And every one is aware of the assistance derived from the encouragement of others, when we are ourselves doubtful of our powers; and of the detrimental influence of discouragement or suggested doubt, even when we previously felt a considerable confidence of success.† These familiar facts show us, therefore, that the phenomena just described as occurring in abnormal states, are in no respect contrary

* The Author has every reason to believe that the personal character of this individual placed him above the suspicion of deceit; and it is obvious that if he had *practised* the first of the above performances (which very few, even of the strongest men, could accomplish without practice), the effect would have been visible in his muscular development. Of course, there was not an equal proof of the absence of deception in the second case as in the first; but if the reality of the first, and the validity of the explanation above given, be admitted, there need be no difficulty in the reception of the second, since it is only another manifestation of the same mental condition. Of the almost superhuman strength and agility with which the body seems endowed, when the whole energy is concentrated upon some nervo-muscular effort, especially under the influence of an overpowering emotion, the following remarkable example has been communicated to the Author by a gentleman on whom he can place full reliance, and who was personally cognizant of the fact. An old cook maid, tottering with age, having heard an alarm of fire, seized an enormous box containing her whole property, and ran down stairs with it, as easily as she would have carried a dish of meat. After the fire had been extinguished, she could not lift the box a hair's breadth from the ground, and it required two men to convey it up stairs again.

† The Author well remembers, several years ago, being among those who tested the validity of the statement put forth in Sir D. Brewster's "Natural Magic," that four persons can lift a full-sized individual from the ground, high into the air, with the greatest facility, if they all take-in a full breath previously to the effort, the person lifted doing the same. He could readily understand, upon physiological principles, that a full inspiration on the part of the *lifters* would have a certain degree of efficacy in augmenting their mus-

to our knowledge of the conditions under which the Will operates in producing muscular movement; but afford, when rightly interpreted, a strong confirmation of the statements already made respecting the nature of those conditions.

668. The Will is exerted, however, not merely in determining the actions of the body, but also in regulating the operations of the Mind; and here, again, we find that its action is limited by certain conditions, the knowledge of which is of great importance. It may be said, generally, that we have no direct power of calling before our consciousness, by a volitional effort, ideas which are not already present there; thus, in the act of Recollection, we can do no more than fix our minds upon those ideas which seem most likely to recall, by an act of suggestion, the one which we desiderate (§ 644). But what we do possess, is the power of excluding some ideas, and of bringing others prominently before our mental vision; and this by the power of *Voluntary Attention*, which is the chief if not the sole means through which the sequence of our thoughts is directed by the Will. It has been already pointed-out, that the Attention may be involuntarily fixed upon certain subjects of consciousness, through the attraction they exert upon the individual mind, in virtue either of its original constitution or of its acquired habitudes; and that this attraction determines much of the automatic action of our faculties (§ 647). When most strongly exerted, it causes the consciousness to be so completely engrossed by one train of ideas, that the mind is, for the time, incapable of any other ideational change, sensory impressions, if felt, not being perceived; and, where the consciousness is most completely concentrated upon the internal operations, the individual being as insensible to external impressions as if he were in a profound sleep. But these automatic tendencies of the mind may be to a certain extent antagonized by the Will, which keeps them in check (just as it restrains many of the automatic impulses to bodily movement) by the special power which it exerts over the Attention. This it can detach from subjects which have at the time the greatest attractiveness for it, and can forcibly direct it to others from which their attraction would otherwise divert it. And in its most complete and powerful exercise (which is not within the capacity of every one), it can so completely limit the mind to one train of thought, that the state of Abstraction induced by the Will may

muscular power; but he could not perceive how the performance of the same act by the *person lifted* could have any appreciable effect; and while many of his acquaintances assured him that, when all the conditions were duly observed, the body went up "like a feather," and that they felt satisfied of being able to support it upon the points of their fingers, he found his own experience quite different, and came to the conclusion, after much observation, that the facility afforded by this method entirely depended upon the degree in which it fulfilled the above-mentioned conditions, namely, the fixation of the attention upon the effort, and the conviction of the success of the method. Whenever the attention was distracted and confidence weakened by scepticism as to the result, the promised assistance was not experienced. The Author may also mention, as a very characteristic illustration of the same principle, the following little circumstance communicated to him by a friend. This gentleman related that, having been accustomed in his boyhood to play at bagatelle with other juniors of his family, the party was occasionally joined by a relative who was noted for her success at the game, and who was consequently much dreaded as an opponent; and that, on one occasion, when she was about to take her turn against him, he roguishly exclaimed, "Now, aunty, you will not be able to make a hit;" the effect of which suggestion was, that she missed every stroke,—and not only at that turn, but through the remainder of the evening.

be as complete as that which in some individuals is of spontaneous occurrence (§ 671).

669. In proportion as we are able thus to concentrate our attention on the subject proper to the time, and to exclude all distracting considerations whilst pursuing the trains of thought which the contemplation of it suggests, will be our power of advantageously employing our Intellectual Faculties in the acquirement of knowledge and in the pursuit of truth; and all men who have been distinguished by their intellectual achievements, have possessed this faculty in a considerable degree. It is one which is "eminently capable of cultivation by steady intention of mind and habitual exercise;" and the more frequently it is put in practice, the easier the exercise becomes. In fact, when a man has once brought his Intellectual faculties under the mastery of his Will, to such an extent as to induce the state of Abstraction whenever he pleases, this state becomes (as it were) 'secondarily automatic;' and the fixed direction of the thoughts, which at first required a *constant* volitional effort for its maintenance, comes to be continued without any consciousness of exertion, so long as the Will may permit.—We have in our own consciousness of effort, and in our experience of subsequent fatigue, a very strong indication that the power which thus controls and directs the current of thought, is of the same *kind* with that which calls-forth Volitional movements of the body, though exerted in a different mode. And just as the strongest exertion of Will is required to produce or sustain Muscular contraction, when the sense of muscular fatigue is already strongly experienced or when we are antagonizing a powerful automatic impulse, so in the determination of Mental effort in a particular direction, we find ourselves necessitated to make the greatest Volitional effort, when we are already labouring under the sense of Cerebral fatigue, or when the attention is powerfully solicited by some other attractive object. And it is after any such contest with our natural tendencies, that we experience the greatest degree of exhaustion; the merely automatic action of the Mind, which is attended with no effort, being followed by comparatively little fatigue.*

* The Author is satisfied from his own experience, that a most valuable indication may be hence drawn, in regard to the regulation of the habits of Intellectual labour. To individuals of ordinary mental activity, who have been trained in the habit of methodical and connected thinking, a very considerable amount of *work* is quite natural; and when such persons are in good bodily health, and the subject of their labour is congenial to them—especially if it be one that has been chosen by themselves, as furnishing a centre of attraction around which their thoughts spontaneously tend to range themselves,—their intellectual operations require but little of the controlling or directing power of the Will, and may be continued for long periods together without fatigue. But from the moment when an indisposition is experienced to keep the attention fixed upon the subject, and the thoughts wander from it unless coerced by the Will, the mental activity loses its spontaneous or automatic character; and more exertion is required to maintain it volitionally during a brief period, and more fatigue is subsequently experienced from such an effort, than would be involved in the continuance of an automatic operation through a period many times as long. Hence he has found it practically the greatest economy of mental labour, to work vigorously when he feels disposed to do so, and to refrain from exertion, so far as possible, *when it is felt to be an exertion*.—Of course this rule is not applicable to all individuals, for there are some who would pass their whole time in listless inactivity if not actively spurred on by the feeling of necessity; but it holds good for those who are sufficiently attracted by objects of interest before them, or who have in their worldly circumstances a sufficiently strong motive to exertion, to make them feel that they *must* work; the question with them being, *how* they can attain their desired results with the least expenditure of mental effort.

670. But this determining power of Volition is employed, in however slight a degree, whenever the succession of thought is not *perfectly spontaneous*,* whenever, in fact, we *wish* our consciousness to take a particular direction, even for the apprehension of ideas most familiar to our minds. And it is especially requisite for the exercise of the *Judgment*, since the comparison of ideas which this involves, can only take place when the Will has the power of selecting those which are appropriate, and of bringing them into collocation with each other. The continual action of the judgment through this medium, is in fact the source of that *common-sense*, whereon we rely in the ordinary conduct of life. We almost unconsciously store up a mass of impressions derived from our habitual experience, by which we are continually testing the validity of new impressions; admitting them if consonant with it, rejecting them if vehemently discordant, and keeping them on trial if we cannot dispose of them in one or other of these modes. The simple credulity of the child, on the other hand, depends upon his having no such stock of experience on which to fall back, for the correction of any erroneous notions which he may himself form, or which may be imparted to him by others. The effort required for this comparison of things present with past experience, when once it comes to be habitual, is so slight as to be scarcely perceptible even to one's self; yet slight as the effort may be, it is the one thing needful; and it may be unhesitatingly laid down, that, if the directing powers of the Will be suspended, the capability of correcting even the most illusory ideas by an appeal to 'common-sense' is for the time annihilated. Of this we have a typical example in the state of Dreaming (§ 691).—Hence we see, that if the Human Mind should lose for a time the power of volitional self-direction, it cannot shake off the yoke of any 'dominant idea' however tyrannical, but *must* execute its behests;—it cannot bring any notion with which it may be possessed, to the test of 'common-sense,' but *must* accept it as a belief, if it be impressed on the consciousness with adequate force;—it cannot recall any fact, even the most familiar, that is beyond its immediate grasp;—upon any idea, therefore, with which it may be possessed, the whole force of its attention is for the time concentrated, so that the most incongruous conception presents itself with all the vividness of reality;—and finally, if the automatic activity of the mind, when freed from the controlling power of the *will*, should depend more upon *external* than upon *internal* suggestion, and hence should take no determinate direction of its own, one idea may be readily substituted for another by appropriate means, and the whole state of the convictions, the feelings, and the impulses to action, may be

* It is hoped that the reader will have been made sufficiently aware by the preceding explanations, that by the terms 'spontaneous' or 'automatic' succession of thought, it is intended to designate that sequence of states of consciousness, in which every one is the immediate resultant of that which preceded it, whether that were ideational or sensational. Thus the current of thought is alike 'spontaneous,' when it flows onwards in one continuous channel (being directed by a single dominant idea which absorbs the whole attention), and when the mind is freely accessible to external impressions and may be entirely guided by them. The phenomena of Reverie, Abstraction, and Somnambulism (as will be presently seen) afford illustrations of *both* these states; which, though apparently opposite in their nature, are really characterised by the same essential feature,—namely, the absence of the directing power of the Will,—and differ only as to the *subjective* or the *objective* character of the suggestions which determine the succession of thought.

thus altered from time to time, without the least perception of the strangeness of the transition.

671. The importance of this directing power of the Will may be best appreciated, by the examination of those curious states in which it is entirely suspended, whilst the Intellect remains in full activity, and the Sensorium is freely open to external impressions. Such states [illegible] show us what we should be, if we really *were*—what some writers [illegible] us that we actually *are*—mere thinking automata, puppets [illegible] direction by the pulling of suggesting-strings. § 580 note) present [illegible] selves *spontaneously* in some individuals, and may be *induced* [illegible] and it is not a little remarkable that they may occur as modifications both of the waking and of the sleeping states. Of the former we have an example in ordinary *Reverie*, a state to which some persons are [illegible] prone; the characteristic of which is, that whilst, as in Dreaming, the succession of thought is entirely automatic, it is in no small degree influenced by external impressions, especially such as arise from the [illegible] phenomena of Nature. It is in minds in which the emotional and imaginative elements predominate, that we usually find the greatest tendency to reverie; and the sequence of thought, if subsequently analysed, will be found to have been chiefly determined by these tendencies. [illegible] sequence may conduct us to notions altogether inconsistent with [illegible] most familiar experience; and yet we accept them as realities notwithstanding this incongruity, because the ideas to which they are opposed are not present to our minds at the time, and the dormant state of the Will prevents us from making the slightest effort to bring them before the consciousness. The state of *Abstraction*, or 'absence of mind,' is essentially the same with that of reverie, the chief difference being that in true Abstraction the mind is at work ratiocinatively, a certain train of thought being followed-out by the intellectual operations to its [illegible] conclusion; so that it is the Philosopher who is most prone to abstraction, as the Poet is to reverie. Now it is one of the most curious phenomena of this state, that external impressions, if received by the consciousness at all, are very often *wrongly* perceived, being interpreted in accordance with the ideas which happen to be dominant in the mind at the time, instead of giving-rise to those new ideas which ordinarily connect themselves with them, in virtue of the individual's habitual experience. The records of 'absence of mind' are full of amusing instances of such [illegible] interpretation. Nothing seems too strange for the individual to [illegible] nothing too absurd for him to do under the influence of that [illegible] Thus of Dr. Robert Hamilton, a well-known Professor at Aberdeen, who was the author of many productions distinguished for their profound and accurate science, their beautiful arrangement, and their clear [illegible] we are informed that, "In public, the man was a shadow; pulled off his hat to his own wife in the streets, and apologized for not having the pleasure of her acquaintance; went to his classes in the college [illegible] dark mornings with one of her white stockings on the one leg and one of his own black ones on the other; often spent the whole time of the meeting in moving from the table the hats of the students, which they constantly returned; sometimes invited them to call on him, and then fined them for coming to insult him. He would run against a cow in the road, turn round, beg her pardon, call her 'Madam,' and hope she

was not hurt. At other times he would run against posts, and chide them for not getting out of his way."*

672. A state may be artificially induced in many individuals, by a continued fixed gaze at an object at a moderate distance, which corresponds with that of Reverie and Abstraction in regard to the complete suspension of the directing power of the Will over the current of thought, but which differs from these in the readiness with which the mind may be possessed with ideas suggested to it through the medium of language. This state has been commonly known by the name *Electro-Biological*, from the mode in which its induction was originally practised;† but it is now more frequently designated by the very inappropriate term *Biological*. The subject of it may be truly characterized as a *thinking automaton*, the whole course of whose ideas may be determined by suggestions operating from without; and his mind, having in itself no power of altering the course of these in even the slightest degree, is cut-off from all recourse to previous experience for the examination of their correctness or the determination of their fallacy. The senses of the biologized subject are freely accessible to external impressions; but, as in the case of the 'absent' man, his perception of these is governed by the ideas which may be dominant in his mind at the time, and he may be consequently led to any kind of absurd misinterpretation of them. Yet his state of mind is not so far removed from his ordinary condition, as to prevent his usual habits of thought and feeling from displaying themselves; and he has in most cases a perfect recollection of what has taken place, when he returns to his usual condition of mental activity, though sometimes the recollection does not extend to particulars. All the phenomena of the 'biologized' state, when attentively examined, will be found to consist in the occupation of the mind by the *ideas* which have been suggested to it, and in the influence which these ideas exert upon the actions of the body. Thus the operator asserts that the 'subject' cannot rise from his chair, or open his eyes, or continue to hold a stick; and the 'subject' thereby becomes so completely possessed with the fixed belief of the impossibility of the act, that he is incapacitated from executing it, *not* because his will

* See "New Monthly Magazine," vol. xxviii. p. 510.—The Author has heard from an old pupil of Dr. Hamilton an anecdote so singularly illustrative of this peculiar condition, that he cannot refrain from here introducing it. The Professor, walking one day along the High Street with the front of his breeches open (no very unusual occurrence with him), chanced to encounter a woman in a white apron, and apparently mistaking this for his own shirt, he laid hold of it, and began to push it into the situation which his shirt should occupy.

† The "Electro-Biologists," as they termed themselves, at first maintained that a wonderful virtue resided in the little disk of copper with a zinc centre, to which they directed the gaze of their '*subjects*.' It is now universally admitted, however, that *any* object which serves as a *point d'appui* for the fixed gaze, is equally efficacious. The Author has no hesitation in avowing his belief in the *reality* of the phenomena, which are described as occurring in this state; these having been presented to himself and to other scientific inquirers, by numerous individuals, on whose honesty and freedom from all disposition to deceive themselves or others, implicit reliance could be placed. All *public exhibitions*, the performers in which are of questionable character, are of course open to the obvious suspicion of intentional deceit. With regard to the *interpretation* of these phenomena, however, he entirely dissents from the statements commonly made, to the effect that the Will of the 'biologized' subject is entirely under the control of that of the operator; since he regards the latter as having no other influence over the former, than through the *suggestions* which his language and manner convey.

is controlled by that of another, but because his will is in abeyance and his muscles are entirely under the guidance of the conviction which for the time possesses his mind. So again, when he is made to drink a glass of water, and is assured that it is coffee, or wine, or milk, that assurance, delivered in a decided tone, makes a stronger impression on his mind than that which he receives through his taste, smell, or sight; and not being able to judge and compare, he yields himself up to the 'dominant idea.'* Here, again, we perceive that it is not really the *will* of the operator which controls the *sensations* of the subject; but the *suggestion* of the operator which excites a corresponding *idea*, the falsity of which is not corrected, simply because the mind of the subject, being completely engrossed by it, cannot apprehend the truth less forcibly impressed on it through his own senses.—The same general statement applies to what has been designated as 'control over the memory.' The subject is assured that he cannot remember the most familiar thing, his own name for example; and he is prevented from doing so, not by the will of the operator, but by that conviction of the impossibility of the mental act which engrosses his own mind, and by the want of that voluntary command over the direction of his thoughts, which alone can enable him to recall the desiderated impression. And the abolition of the sense of personal identity (Mr A. believing himself to be Mrs. B., or Mrs. C. believing herself to be Mr. D., and acting in conformity with that belief) is induced in the same mode; the assurance being continually repeated, until it has taken full possession of the mind of the 'subject,' who cannot so direct his thoughts as to bring his familiar experience to antagonize and dispel the illusive idea thus forced upon him. The phenomena presented by different 'biologized subjects' are by no means the same; for in some individuals it is the relation of the mind to bodily action which is most remarkably affected, in others it is the relation of the perceptive consciousness to sensations, and in others (especially those who are naturally of an imaginative and excitable disposition) it is the course of thought and of emotion which is most completely under external guidance. It is frequently to be observed, moreover, that some capability of volitional effort still remains, so that the 'subject' endeavours to resist the command of the operator; but this may usually be subdued by the emphatic reiteration of the assurance "You *must* do this," or "You *cannot* do that," which, when it takes complete possession of the mind of the subject, reduces the will to a state of entire powerlessness.†

* It is very curious to observe, in some instances, the perplexity arising from the contrariety between the opposing sensory impressions. The mind seems aware of this contrariety, and yields itself up to the impression which is most strongly [illegible]. Sometimes it is convinced by the repeated assurances of the operator, [illegible] *taste* alone is opposed to them, but attaches a superior importance to [illegible] *sight*; in other individuals, again, the indications of sight may be put aside, [illegible] 'subject' cannot be made to believe what is in opposition to his sense of taste. [illegible] some individuals who can never be thus played upon, notwithstanding that their [illegible] movements and their purely mental conceptions are completely amenable to [illegible] direction.

† It is worthy of particular notice in this connection, that this want, not really [illegible] to move, but of belief in the possession of the power, is a frequent chara[illegible] state of the nervous system which is commonly designated as 'Hysteria' [illegible] also, the most efficacious treatment consists in the encouragement of v[illegible] part of the patient to put the paralysed limbs in action, and in the repetition of [illegible]

673. It is obvious that if the account here given of the condition of the Mind, and of the mode of its operation on the Body, in the states of natural and artificial Reverie and Abstraction, be correct, all the actions performed in these states must be regarded as essentially *automatic* in their nature; the course of thought being entirely determined by the play of Suggestions upon the associations previously formed, and all the bodily movements being the direct manifestations of the *ideas* which possess the mind at the time, just as the ordinary movements of 'expression' are of its *emotions*. And it is, therefore, in these remarkable phases of psychical existence, that we have the clearest manifestation of the power which Cerebral changes possess, to produce muscular movement independently either of Volition or of Emotion; an action which may be distinguished as *ideo-motor*, since it only takes place when these changes are of a kind to awaken the ideational consciousness; and which is a true 'reflex' action of the Cerebrum.

674. Returning now from the consideration of these Pathological conditions of Mind (as they may be not unfairly designated) to the examination of the Psychical constitution of Man in the state of normal activity of his faculties, we shall find that very important data may be drawn from these sources, with regard to the *modus operandi* of the Will, and the manner in which our conduct is determined. For we have seen that, in so far as the directing influence of the Will over the current of thought is suspended, the individual becomes a thinking automaton, destitute of the power to withdraw his attention from any idea or feeling by which his mind may be possessed, and as irresistibly impelled, therefore, to act in accordance with this, as the lower animals are to act in obedience to their instincts. In so far, therefore, as this directing influence is not exercised, the succession of trains of thought which occupy the consciousness (associated, or not, with feelings that give them an *emotive* character) must be considered as dependent on the 'reflex action' of the Cerebrum; the nature of this action being determined, not merely by the original constitution of the organ, but by the mode in which it has been subsequently exercised; its nutrition taking place in such conformity to the impressions made upon it, and to the modes in which it is habitually directed by the Will, that it *grows-to* these, so that a new organization thus comes to be established, by which *habits of thought* are determined, such as would not have arisen from its original constitution.* The variety of phases which these different states present, is chiefly dependent upon the following elements;—(1) the relative degree in which the Mind is in a state of receptivity for external impressions, or is attending only to what passes within itself; (2) the degree in which

that she *will* recover the use of them, if she only take the appropriate means. The expectation of recovery excited in other ways, produces the same effect, and thus it has been, that many pseudo-miracles have been wrought on this class of patients by Religious enthusiasts, and that many wonderful cures have been effected by the supposed influence of Mesmerism. All that is wanted, is that state of *confident anticipation*, which is commonly designated as Faith. (See § 537.)

* See Dr. Laycock's Essay 'On the Reflex Function of the Brain,' in the "Brit. and For. Med. Review," vol. xix. p. 298.—The Author would beg to refer-back to the antecedent portions of this inquiry, and especially to §§ 557, 558, as showing to what extent he regards the *organization* of the Cerebrum as determining its mode of *psychical activity*.

the coherence of the successive states is maintained by the continuance and right operation of the preformed associations, so that trains of thought are consistently carried-out, and reasoning processes correctly performed; and (3) the degree in which the normal operation of the intellectual faculties is disturbed by emotional excitement, either general, or limited to one class of feelings. The influence of the *first* of these elements is remarkably seen in the contrast between natural and artificial Reverie (§§ 671, 672); also between some forms of natural and artificial Somnambulism (§ 693–695); and not less between different forms of Insanity, since in this last condition we find some patients constantly brooding over particular trains of thought, and almost incapable of being turned from the contemplation of these by external suggestions, whilst others are no less remarkable for the instability of their mental states, and for the readiness with which a new direction may be given to the thoughts by sensory impressions. The influence of the *second* element is strikingly manifested in the difference between the various phases of the state of Dreaming, and in the contrast between the incoherence of the commoner forms of this (§ 691), and that consistency in the trains of thought which generally characterizes the state of Somnambulism; but it is yet more remarkably displayed in those forms of Delirium and Insanity (§ 706), which are especially characterized by the complete *confusion* of the Intellectual powers, all previous states of consciousness being (as it were) jumbled-together, and the order of their recurrence and the nature of the new combinations which may arise out of them, being irreducible to any principle of orderly sequence. The influence of the *third* element is well seen in those forms of artificial Reverie and Somnambulism, in which the *feelings* as well as the *ideas* admit of being played-upon by external influences; for it is easy to bring the mind of the 'subject' under the domination of any particular emotion, by taking the appropriate means to excite it,* and, so long as this may continue, the language and actions most obviously display its impress. But it is in Insanity (Sect. 8) that we best see the influence of Emotional states upon the course of thought and of action; for here we find them supplying impulses to bodily action, which the weakened Will cannot resist, although the intellect distinctly apprehends the evil consequences of such actions; or, on the other hand, we find them directing the whole course of mental activity, giving a wrong colour to all the ideas which are related to them, and so attracting the attention to the trains of thought founded upon these, that they come to attain a complete domination over the mind, and hence over the conduct, to which they supply *motives* of such potency that the Will can neither resist them, nor withdraw the mind from attending to them.

675. Thus, then, we see that in all those states in which the directing power of the Will over the current of *thought* is suspended, the course of *action* is determined by some *dominant idea*, which for the time has full possession of the mind, and from which the individual has no power of

* Thus in the 'biologized' state (§ 672), it is often sufficient to ask the 'subject' "Why are you so angry," "Why are you so sad," &c., to induce these emotions respectively, the suggestions being here conveyed verbally; whilst in the 'hypnotic' state hereafter to be described, there is a very curious susceptibility to the influence of muscular associations on emotional states (§ 694).

withdrawing his consciousness; the *motive power* of this idea being such as either impels to action by a feeling of internal necessity (analogous to that which prompts the reflex actions of the Cranio-Spinal axis), or solicits it by the anticipation of pleasure in its result or of pain in abstinence from it. On the other hand, the man in full possession of his Volitional faculty, whilst equally amenable with those in the foregoing states to the influence of the motive power of ideas, differs from them all in this most important particular,—that he has the power of refraining from action under the immediate pressure of motives, and of so far *modifying their relative force* by the mode in which he contemplates them, that their original balance may be completely altered; and hence his ultimate determination, whilst still governed by the *predominance of motives*, may be entirely different from that on which he would have acted, if he had given way to his first impulse. For just as we may direct our Intellectual operations by an exercise of Volition, so as to fix upon certain *ideas* only, out of the many which present themselves to our consciousness, and to limit our attention to certain peculiar aspects of these (§ 640), so may we fix our attention upon any one or more among the *motives* which tend to determine our action, and keep these (as it were) in a strong light before the mind's eye, whilst by withdrawing our attention from others, we virtually throw them into the back-ground, as we can do with regard to objects of Sensation (§ 592). And further, by calling the Reasoning powers into operation, and bringing them to bear upon the questions at issue, so as to follow out each of the modes of action that are before the mind to its probable consequences, the Will indirectly brings a set of new motives, arising out of these consequences, before the judgment; and these, at first overlooked, may become important elements in the decision. On the other hand, it may be that in this reasoning-out the probable consequences of an action, motives which at first presented themselves in great strength, lose more or less of their force, and even become altogether futile.—It is in these modes that 'second thoughts' generally prove to be the best, save where selfish considerations are brought to take the place of primary generous impulses; whilst a hasty determination often leads to wrong action, because all the motives that should be taken into account have not been duly weighed.*

676. Now if we examine into the different kinds of *Motive Powers*, which, under the permission or the intentional direction of the Will, are the sources of Human action, we shall find that they may be ranged under the following heads:—(1) *Previously acquired Habits*, which automatically incite us to do as we have been before accustomed to do under the like circumstances, without the idea of prospective pleasure or pain, or of right or wrong, being at all present to our minds. The

* It has been held by some, that when a man is struggling with a temptation, and the motives to good and the motives to evil are nearly in equilibrium, like weights in the two scales of the balance, the Will acts as an independent preponderating power, like a hand pressing down the scale-beam on one side. It appears to the Author, however, to be much more conformable to the results of a careful examination of our own conduct, to regard the Will as imparting an augmented gravity (as it were) to the weights on one side, by directing attention to their value, and by indirectly making additions to them, in the manner stated above, whilst it diminishes the force of those on the other side, by preventing the mind from giving its attention to them, and also (it may be) by virtually abstracting some of them from the scale.

formation of Habits, both of thought and action, seems referable to the psychical principle of Contiguous Association (§ 632) and to the physiological principle of Nutritive Assimilation (§ 346), which, in regard to the operations of the Cerebrum, seem to be only different expressions of the same fact; namely, that whatever mode of activity has been once strongly impressed on the organ, this has a tendency to perpetuate itself. In so far as the Will yields to this tendency, instead of controlling it, the individual becomes the slave of *routine;* and this condition is often very remarkably presented by persons who are deficient in Volitional power (as it is also among the lower animals), from whose actions we may derive our best illustrations of what Habit will do, when it is not under the direction of any higher principle.* The tendency to habitual action is so universally recognized as an important part of our psychical nature, that Man has been said to be 'a bundle of habits.' Where the habits have been judiciously formed in the first instance, the tendency is an extremely useful one, prompting us to do that spontaneously, which might otherwise require a powerful effort of the Will.†

* It is not uncommon to meet with Idiots, in whom the tendency to the automatic recurrence of modes of action once impressed on the consciousness, is extremely remarkable. The following is stated by Miss Martineau, in regard to a youth under her own observation, who, in consequence of early injury to the brain, never acquired the power of speech, or of understanding the language of others, or of in any way recognizing other minds; but was at the same time strongly affected by sensory impressions. "He could endure nothing out of its position in space or its order in time. *If any new thing was done to him at any minute of the day, the same thing must be done at the same minute every day thenceforward.*" Thus, although he disliked personal interference, his hair and nails having been one day cut at ten minutes past eleven, the next day, and every day after, at ten minutes past eleven, he "as if by a fate," brought comb, scissors, and towel; and it was necessary to cut a snip of hair before he would release himself. Yet he had no knowledge whatever of the measurement of time by clocks and watches, and was no less minutely punctual in his observances when placed beyond the reach of these aids. So in regard to form, number, and quantity, his actions were equally methodical. He occupied himself much in making paper cuttings, which were remarkable for their symmetry. If, when he was out of the room, a brick were taken from the heap with which he amused himself, he would pass his hand over them, spread them a little, and then lament and wander about till the missing one was restored. If seven comfits had once been put into his hand, he would not rest with six; and if nine were given, he would not touch any until he had returned two. ("Letters on the Laws of Man's Nature and Development," p. 71. See also "Household Words," vol. ix. p. 198.) It would be easy to adduce multitudes of analogous instances from the actions of animals, especially such as are purposely *trained* to particular habits, by taking advantage of the principle of 'contiguous association,' which seems to be peculiarly strong in Dogs, Horses, &c. And the recurrence of particular actions at particular intervals of time, without any means of consciously estimating its passage, or any incidents that can suggest the return of the period, is a very curious indication of the degree in which organic changes in the Nervous System, once determined by a certain number of repetitions, tend to perpetuate themselves. Thus a dog that has been accustomed to receive food at a certain hour and place every day, will come in search of it with extraordinary punctuality; and the horse of a commercial traveller, after going the same journey a few times, will stop at the houses of all his master's customers, and when he has been pulled-up at a new point on one journey, will spontaneously stop at the same point on the next,—a fact of which the Author has personal knowledge.

† This is especially the case with regard to habits of Intellectual exertion, which are in themselves peculiarly free from any emotional complication. The Author can speak from long and varied experience, of the immense saving of exertion which arises from the formation of *methodical habits* of mental labour, which cause the ordinary routine to be performed with a far less amount of fatigue, than would be required on a more desultory system (§ 647). Even here, however, care should be taken to avoid allowing oneself to be so much the slave of habits, that all mental labour, save that which is undertaken at a particular time, or in a particular place, becomes difficult and wearisome.

but, on the other hand, if a bad set of habits have grown-up with the growth of the individual, or if a single bad tendency be allowed to become an habitual spring of action, a far stronger effort of Volition will be required to determine the conduct in opposition to them. This is especially the case, when the habitual idea possesses an Emotional character, and becomes the source of *desires;* for the more frequently these are yielded-to, the more powerful is the solicitation they exert.—(2). *Emotional States*, which incite us to particular actions, by the expectation of gratification either in the act itself or in some consequence which our reason leads us to anticipate from it, or by the expectation of pain if the act be not performed. All those *desires* and *aversions* which have so large a share in determining our conduct, come under this category, and to it must likewise be referred all those considerations which are simply *prudential*, these usually having reference to the *remoter* effects which our actions are likely to have upon our own welfare or upon that of others, and thus bringing before the mind, as elements in its determination, certain additional objects of desire or aversion.—(3). *Notions of Right and of Duty*, which, so far as they attach themselves to our actions, give them a *moral* and *religious* character. These may act simply as *ideas*, whose coercive power depends upon the intensity with which they are brought before the mind; but they obtain a much stronger influence, when they acquire an Emotional character from the association of the feeling of *desire* with the idea of *obligation;* that is, when we feel a *wish* to do that which we are conscious we *ought* to do. This association is one, which it is peculiarly within the capability of the Will to cherish and strengthen. And still more powerful is the operation of these combined motives, when a constant *habit* of acting upon them has been formed; for the strongest desires are then immediately repressed, the strongest aversions cease to exert an influence, when once the question is looked at in its Moral aspect, and a clear perception has been attained of its right and its wrong side.*

* The difference between the *habitual*, the *prudential*, and the *moral* aspects of the very same action, may be made apparent by a very simple illustration. We will suppose that a man has been accustomed to take a ride every day at a particular hour, his whole nature so accommodates itself to the *habit*, that he feels both mentally and physically uncomfortable at any interruption to the usual rhythm. But suppose that, just as the appointed hour comes round, the sky becomes overcast, threatening the rider with a drenching if he perseveres in his intention, his decision will then be founded on a *prudential* consideration of the relative probabilities of his escaping or of his being exposed to the shower, and of how far the enjoyment he may derive from his ride is likely to be replaced by the discomfort of a thorough wetting. But suppose, further, that instead of taking a mere pleasure-ride, a Medical man is about to set forth on a professional visit to a patient whose condition requires his aid, a new motive is thus introduced, which alters the condition of the whole question, making it no longer one of prudence only, but one of *morality*. Another motive which should give the question a moral aspect, would be consideration for himself, and the risk of life or health he might run; this should be decisive, where the motive which impels him to the act in question is merely that of self-gratification; but if it bring into antagonism his duty to his patient and his desire to benefit him, and on the other hand his duty to himself and his regard for the ulterior welfare of those who may be immediately dependent upon him, the question has its right and its wrong aspect on both sides (§ 617), and the right may only be determined after a careful balance of probabilities. Such moral conflicts are continually occurring amongst Medical Practitioners, in regard to exposure to the severity of the weather, to dangerous infection, or to risks of other kinds; and the decision will mainly depend upon the previously-formed habit, on the one hand of disregarding all considerations connected with self, on the other of attaching especial weight to them.

677. From the time when the Human being first becomes conscious that he has a Volitional power within himself of *determining the succession* of his mental states, from that time does he begin to be responsible for it; and in proportion as he exerts that power, does he emancipate himself from the domination of his constitutional or automatic tendencies, and make himself a *free agent*. It is a principle now recognized by all the most enlightened Educators, that the development of this power of self-control ought to be the object of all nursery discipline; and the process of its acquirement is very gradual. When an infant is excited to a fit of passion by some unpleasant sensation, its nurse attempts to restore its equanimity by presenting some new object to its attention, so that the more recent and vivid pleasurable impression may efface the sense of past uneasiness. As the infant grows into childhood, the judicious parent no longer trusts to mere sensory impressions for the diversion of the passionate excitement, but calls up in its mind such ideas and feelings as it is capable of appreciating, and endeavours to keep the attention fixed upon these, until the violence of the emotion has subsided; and recourse is had to the same process, whenever it is desired to check any tendency to action which depends upon the selfish propensities,—appeal being always made to the highest motives which the child is capable of recognizing, and punishment being only had recourse-to, for the purpose of supplying an additional set of motives when all others fail. For a time, this process of external suggestion may need to be continually repeated, where there are strong impulses whose unworthy character calls for repression; but if it be judiciously adapted and consistently persevered-in, a very slight suggestion serves to recall the superior motives to the conflict. And in further space, the child comes to feel that he has *himself* the power of recalling them, and of controlling his urgent impulses to immediate action. The power of self-control, thus usually acquired in the first instance in regard to those impulses which directly determine the conduct, gradually extends itself to the habitual succession of the thoughts; and in proportion as this is brought under the direction of the Will, does the individual become capable of forming his own character, and of guiding his actions according to the indications of his Moral Sense.

678. It must not be forgotten, however, that the power of self-control may be turned to a bad as well as to a good account, and that the value of its results will entirely depend upon the *direction* in which it is employed. The thoughts may be so determinately drawn-away from the higher class of motives, the suggestions of conscience so habitually disregarded, and the whole attention so completely fixed upon the gratification of selfish or malevolent propensities, that the Human nature acquires far more of the *Satanic* than of the Divine character, the highest development of this type (if the term may be permitted) being displayed by those, who use their power of self-control for the purposes of hypocrisy and dissimulation, and cover the most malignant designs under the veil of friendship. Such men (whose portraiture is presented by our great Dramatist in the character of Iago) show us to what evil account the highest Intellect and the most powerful Will may be turned, when directed by the baser class of motives; and we cannot but feel that

they are far more degraded in the moral scale, than those who, having never learned to control their animal propensities, and being unconscious of the very existence of a higher nature within themselves, simply obey the promptings of their automatic impulses, and are rather to be considered as ill-conditioned automata, than as vicious men.—Of this latter class, some, from original constitution and early influences of the most degrading kind, seem altogether destitute of anything but a *brutal* nature; these ought to be treated as irresponsible beings, and, as such, restrained by external coercion from doing injury to society. But this class is small in proportion to that of individuals who *act* viciously, simply because they have never been led to *know* that any other course is open to them, or to *feel* any motives that might give them a different impulse. With these, the object should rather be to awaken the higher parts of the moral nature, "to find out the holy spot in every child's heart," and to develope habits of self-control in the manner just described, than to subjugate by external restraint; and the success which has attended this method, in the hands of those who have judiciously applied it, is sufficient evidence of its superiority; many of the most apparently-debased natures having been thus elevated to a grade, which it seemed at first impossible they could ever attain.

679. From the Satanic, or positively and wilfully-evil type of Human nature, in which the highest powers are turned to the worst account, we are thus conducted through the *brutal* or negatively-evil type, towards that higher aspect of Humanity, which is presented by those who habitually keep before them the *Divine* ideal, and who steadily endeavour to bring their *whole nature* into conformity with it. This is *not* to be effected by dwelling *exclusively on any one* set of the motives already referred-to (§ 618), as those which the truly religious man keeps before his mind. Even the idea of Duty, *operating alone*, tends to reduce the individual to the subservience of a slave, rather than to induce in him that true mastery over himself, which consists in such a regulation of his emotions and propensities, that his course of duty becomes the spontaneous expression of his own higher nature; but it is a most powerful aid in the acquirement of that regulation, by the fixation of the thoughts and affections on "things on high," which is the best means of detaching them from all that is earthly and debasing. It is by the *assimilation*, rather than by the *subjugation*, of the Human Will to the Divine, that Man is really lifted towards God; and in proportion as this assimilation has been effected, does it manifest itself in the life and conduct; so that even the lowliest actions become holy ministrations in a temple consecrated by the felt presence of the Divinity. Such was the life of the Saviour; towards that standard it is for the Christian disciple to aspire.*

* The careful study of the Epistles of St. Paul will show this to be the *dominant idea* of this Apostle's teachings. Under the name of "the Law," he continually refers to the spirit of bondage or external coercion, which "was the schoolmaster to bring us to Christ;" whilst under the designation of "the Gospel" he obviously desires to express that spirit of internal freedom or self-direction, which is the source of all that is truly noble in the Christian character.

Section 7.—*Of Sleep and Somnambulism.*

680. It is a peculiar feature in the physiology of the Cerebral and Sensorial Ganglia, that their activity undergoes a periodical suspension, more or less complete; the necessity for this suspension arising out of the fact that the exercise of their functions is in itself destructive to their substance, so that, if this be not replaced by nutritive regeneration, they speedily become incapacitated for further use. In ordinary profound Sleep, there is a state of complete unconsciousness, so far as *external* phenomena are concerned; no ordinary impressions upon the organs of sense being either felt or perceived; although an extraordinary impression, or even an habitual one upon which the attention has been previously fixed as that at which the slumberer is to awake himself (§ 687), occasions a renewal of sensorial activity. It is in this capability of being aroused by external impressions, that the chief difference lies between Sleep and the abnormal condition of Coma, whether this arise from the influence of pressure or effusion within the cranium, or be consequent upon the poisoning of the blood by narcotic substances, or follow a previous state of abnormal activity of the brain, such as Delirium (§ 715). Between these two conditions, however, every gradation may be seen; as in the gradually increasing torpor which results from slow effusion within the cranium, the gradual loss of susceptibility to external impressions which is observed after an over-dose of a narcotic, and the intensification of ordinary sleep which is consequent upon extreme previous fatigue. It is a matter of doubt, however, whether the suspension of sensorial consciousness is equally complete as regards *internal* or Cerebral changes; for some are of opinion that, even in the most profound sleep, we still dream, although we may not remember our dreams; whilst others (and among these the Author would rank himself) consider that dreaming is a mark of imperfect sleep, and that, in profound ordinary sleep, the Cerebrum, in common with the Sensory Ganglia, is in a state of complete functional inactivity. When Dreaming takes place, there is usually a less complete exclusion of sensory impressions, although the perceptive consciousness may be entirely suspended; so that the course of the dream may be influenced by them, although the mind is not conscious of them as such (§ 692). If this be the true account of the case, we may consider that, in profound Sleep, the functional activity of the Cerebrum and of the Sensory Ganglia is alike suspended; but that in Dreaming, the Cerebrum is partially active, whilst the Sensorium is in such a condition of receptivity for Cerebral (subjective) impressions that the mind becomes directly conscious of them, though it only becomes conscious of (objective) impressions made upon the Organs of Sense, after their influence has been transmitted through it to the Cerebrum, and has been, as it were, reflected back by that organ. It is in fact, by their influence upon the current of *ideas*, and not by their power of exciting *sensations*, that we recognize their operation under such circumstances.

681. The state of Sleep is one to which there is beyond doubt a *periodical* tendency; for, when the waking activity has continued during a considerable proportion of the twenty-four hours, a sense of fatigue is

usually experienced, which indicates that the brain requires repose; and it is only under some very strong physical or moral stimulus, that the mental energy can be sustained through the whole cycle. In fact, unless some decidedly abnormal condition of the Cerebrum be induced by the protraction of its functional activity, Sleep will at last supervene, from the absolute inability of the organ to sustain any further demands upon its energy, even in the midst of opposing influences of the most powerful nature.* That the strongest Volitional determination to remain awake, is forced to give-way to Sleep, when this is required by the exhaustion of nervous power, must be within the experience of every one; and the only way in which the Will can even retard its access, is by determinately fixing the consciousness upon some definite object, and resisting every tendency in the thoughts to wander from this. It does not appear to be of any consequence, whether this exhaustion be produced by the active exercise of volition, reflection, emotion, or simple sensation; still we find that the *volitional* direction of the thoughts, in a course different from that in which they tend spontaneously to flow, is productive of far more exhaustion than the automatic activity of the mind (§ 647); whilst, on the other hand, the excess of *automatic* activity, whether as regards the intellectual operations or emotional excitement, tends to prevent sleep. This is particularly the case when the feelings are strongly interested; thus the strong desire to work-out a result, or to complete the survey of a subject, is often sufficient to keep-up the intellectual activity as long as may be requisite (a state of restlessness, however, being often induced, which prevents the access of sleep for some time longer); so, again, anxiety or distress is a most frequent cause of wakefulness; and it is generally to be observed that the state of *suspense* is more opposed to the access of sleep, than the greatest joy or the direst calamity when certainty has been attained.† But although an excess of automatic activity is opposed, so long as it continues, to the access of sleep, yet it cannot be long protracted without occasioning an extreme exhaustion of nervous power, which necessitates a long period of tranquillity for its complete restoration.

682. Whilst, however, the necessity for Sleep arises out of the state of

* Thus it is on record, that, during the heat of the battle of the Nile, some of the over-fatigued boys fell asleep upon the deck; and during the recent attack upon Rangoon, the Captain of one of the war steamers most actively engaged, worn out by the excess of continued mental tension, fell asleep, and remained perfectly unconscious for two hours, within a yard of one of his largest guns, which was being worked energetically during the whole period.—So even the severest bodily pain yields before the imperative demand occasioned by the continued exhaustion of the powers of the sensorial centres; thus Damiens slept upon the rack, during the intervals of his cruel sufferings; the North American Indian at the stake of torture will go to sleep on the least remission of agony, and will slumber until the fire is applied to awaken him; and the Medical Practitioner has frequent illustrations of the same fact.—That the continued demand for muscular activity is not incompatible with the access of sleep, is obvious from what has been already said of the persistence of the automatic movements in that condition (§ 514); it is well known that, previously to the shortening of the hours of work, factory children frequently fell asleep whilst attending to their machines, although well aware that they should incur severe punishment by doing so.

† Thus it is a common observation, that criminals under sentence of death sleep badly, so long as they entertain any hopes of a reprieve; but when once they are satisfied that their death is inevitable, they usually sleep more soundly, and this even on the very last night of their lives.

the nervous system itself, there are certain external conditions which favour its access; and these, in common parlance, are termed its predisposing causes. Among the most powerful of these, is the *absence* of sensorial impressions; thus, darkness and silence usually promote repose; and the cessation of the sense of muscular effort, which takes-place when we assume a position that is sustained without it, is no less conducive to slumber. There are cases, however, in which the *continuance* of an accustomed sound is necessary, instead of positive silence, the cessation of the sound being a complete preventive of sleep; thus it happens that persons living in the neighbourhood of the noisiest mills or forges, cannot readily sleep elsewhere. Such cases are referable, either to the influence of *habit*, which causes the attention of the individual to be more attracted by the suspension of the sound than by its continuance; or to the fact that the *monotonous repetition* of sensorial impressions is often more favourable to sleep than their complete absence. Thus it is within the experience of every one, that the droning voice of a heavy reader on a dull subject, is often a most effectual hypnotic; in like manner, the ripple of the calm ocean on the shore, the sound of a distant waterfall, the rustling of foliage, the hum of bees, and similar impressions upon the auditory sense, are usually favourable to sleep; and the muscular and tactile senses may be in like manner affected by an uniform succession of gentle movements, as we see in the mode in which nurses 'hush-off' infants, or in the practice of gently rubbing some part of the body, which has been successfully employed by many who could not otherwise compose themselves to sleep. The reading of a dull book acts in the same mode through the visual sense; for the eyes wander-on from line to line and from page to page, receiving a series of sensorial impressions which are themselves of a very monotonous kind, and which only tend to keep the attention alive, in proportion as they excite interesting ideas.

683. In these and similar cases, the influence of external impressions would seem to be exerted in withdrawing the mind from the distinct consciousness of its own operations (the loss of which is the transition-state towards that of complete unconsciousness), and in suspending the directing power of the Will. And this is the case, even where the attention is in the first instance *voluntarily* directed to them, as in some of the plans which have been recommended for the induction of sleep, when there exists no spontaneous disposition to it. In other methods, the attention is fixed upon some internal train of thought, which, when once set-going, may be carried on automatically; such as counting numbers, or repeating a French, Latin, or Greek verb. In either case, when the sensorial consciousness has been once steadily fixed, the monotony of the impression (whether received from the Organs of Sense, or from the Cerebrum) tends to retain it there; so that the Will abandons, as it were, all control over the operations of the mind, and allows it to yield itself up to the soporific influence. This last method is peculiarly effectual, when the restlessness is dependent upon some mental agitation, provided that the Will has power to withdraw the thoughts from the exciting subject, and to reduce them to the tranquillizing state of a mere mechanical repetition.

684. The access of Sleep is sometimes quite sudden; the individual passing at once from a state of complete mental activity to one of entire

torpor. More generally, however, it is gradual; and various intermediate phases may be detected, some of which bear a close resemblance to the state of Reverie, whose peculiar nature has been already described (§ 671). The same may be said with regard to the transition from the state of Sleep to that of wakeful activity; and this also may be sudden and complete, although it usually consists of a succession of stages, —the complete consciousness of the individual's relation to the external world, and the power of directing his thoughts and actions to any subject about which he may be required to exert himself, being the last to return to him. There may be a rapid alternation of these different states; the loss and recovery of the waking consciousness being many times repeated in the course of a few minutes, when the circumstances are such as to prevent the access of profound sleep by the recurrence of sensory impressions, as when a man on horseback, wearied from want of rest, lapses at every moment into a dozing state, from which the loss of the balance of his body as frequently and suddenly arouses him; or when a man going to sleep in a sitting posture, gradually loses the support of the muscles which keep his head erect, his head droops by degrees and at last falls forwards on his chest, and the slight shock thence ensuing partially arouses and restores his voluntary power, which again raises the head. Similar fluctuations occur in the sensory perceptions; and these may be often artificially induced by very simple means. "We find, for example, one condition of sleep so light, that a question asked restores consciousness enough for momentary understanding and reply; and it is an old trick to bring sleepers into this state, by putting the hand into cold water, or producing some other sensation, not so active as to awaken, but sufficient to draw the mind from a more profound to a lighter slumber. This may be often repeated, sleep still going on; but make the sound louder and more sudden, and complete waking at once ensues. The same with other sensations. Let the sleeper be gently touched, and he shows sensibility, if at all, by some slight muscular movement. A ruder touch excites more disturbance and motion, and probably changes the current of dreaming; yet sleep will go on, and it often requires a rough shaking, particularly in young persons, before full wakefulness can be obtained." * * * "It is certain that the faculties of sensibility and volition are often unequally awakened from sleep. The case may be stated, familiar to many, of a person sleeping in an upright posture, with the head falling over the breast; in whom sensibility is suddenly aroused by some external impression, but who is unable, for a certain time, to raise his head, though the sensation produced by this delay of voluntary action is singularly distressing." These various cases, it is justly remarked by Sir H. Holland,* depending severally on the intensity of sleep, and on the kind and degree of the external exciting causes, will be found to explain many of those so-called Mesmeric phenomena, which are offered to us under a widely different interpretation. And it may be here remarked, that among those intermediate states between sleep and waking, which either occur spontaneously, or can be induced in numerous individuals by very simple processes (§§ 672, 693), there are several which exhibit peculiarities that are not in themselves in the least degree less remarkable, than are those which are

* See his excellent Chapter on 'Sleep,' from which the above extracts are taken, in his "Medical Notes and Reflections," and his "Chapters on Mental Physiology."

regarded with so much wonder by the uninformed observer, when induced by the asserted Mesmeric influence, and paraded as specimens of its power (See § 696 *note.*)

685. It is unquestionable that the supervention of Sleep may be promoted by the strong previous expectation of it; and this is true, not merely of ordinary sleep, but of the states of artificial Reverie and Somnambulism formerly described. Every one knows the influence of habit, not only in regard to 'time,' but also as to 'place and circumstance,' in predisposing to Sleep. Thus, the celebrated pedestrian Capt. Barclay, when accomplishing his extraordinary feat of walking 1000 miles in as many successive hours, obtained at last such a mastery over himself, that he fell asleep the instant he lay down. And the sleep of soldiers, sailors, and others, who are prevented by 'duty' from obtaining regular periods of repose, but are obliged to take their rest at short intervals, may be almost said to come at command; nothing more being necessary to induce it, than the placing the body in an easy position, and the closure of the eyes. It is related that the Abbé Faria, who acquired notoriety through his power of inducing somnambulism, was accustomed merely to place his patient in an arm-chair, and then, after telling him to shut his eyes and collect himself, to pronounce in a strong voice and imperative tone the word "dormez," which was usually successful. The Author has had frequent opportunities of satisfying himself, that the greater success which attends the 'hypnotic' mode of inducing somnambulism (§ 695), in the hands of Mr. Braid, its discoverer, than in that of others, partly lies in the mental condition of his subjects, who come to him for the most part under the confident expectation of its production, and are further assured by a man of very determined will, that it *cannot* be resisted.* And it is one of the most curious phenomena of the 'biological' state (§ 672), that, in many subjects at least, sleep may be induced in a minute or less, by the positive assurance, with which the mind of the individual becomes possessed, that it *will* and *must* supervene.

686. The influence of previous mental states is yet more remarkable, in determining the effects produced upon the sleeper by different sensory impressions. The general rule is, that *habitual* impressions of any kind have much less effect in arousing the slumberer, than those of a new or unaccustomed character. An amusing instance of this kind has been related to the Author, which, even if not literally true, serves extremely well as an illustration of what is unquestionably the ordinary fact. A gentleman who had taken his passage on board a ship of war, was aroused on the first morning by the report of the morning gun, which chanced to be fired just above his berth; the shock was so violent as to cause him to jump out of bed. On the second morning, he was again awoke, but this time he merely started and sat-up in bed; on the third morning, the report had simply the effect of causing him to open his eyes for a moment, and turn in his bed: on the fourth morning, it ceased to affect him at all; and his slumbers continued to be undisturbed by the report, so long as he remained on board. It often happens that sleep is terminated by

* A very amusing instance in which Sleep, having been previously induced by the ordinary 'mesmeric' and then by the 'hypnotic' processes, was brought on by the simple belief that a new process was being put in practice, will be found in the "Brit. and For. Med. Rev.," vol. xix. p. 477

the *cessation* of an accustomed sound, especially if this be one whose monotony or continuous repetition had been the original inducement to repose. Thus, a person who has been read or preached to sleep, will awake, if his slumber be not very profound, on the cessation of the voice; and a naval officer, sleeping beneath the measured tread of the watch on deck, will awake if that tread be suspended.—In this latter case, the influence of the simple cessation of the impression will be augmented by the circumstance next to be alluded-to, which has received too little attention from writers on this subject, but which is of peculiar interest both in a physiological and psychological point of view, and is practically familiar to almost every one.

687. The awakening power of sensory impressions is greatly modified by our *habitual state of mind* in regard to them. Thus, if we are accustomed to *attend* to these impressions, and our perception of them is thus *increased* in acuteness, we are much more easily aroused by them, than we are by others which are in themselves much stronger, but which we have been accustomed to disregard. Thus, most sleepers are aroused by the sound of their own names uttered in a low tone, when it requires a much louder sound of a different description to produce any manifestation of consciousness. The same thing is seen in comatose states: a patient being often found capable of being momentarily aroused by shouting his name into his ear, when no other sound produces the least effect.—The following circumstance, communicated to the Author by the late Sir Edward Codrington, is a most apposite illustration of this principle. When a young man, he was serving as signal lieutenant under Lord Hood, at the time when the French fleet was confined in Toulon harbour; and being desirous of obtaining the favourable notice of his commander, he devoted himself to his duty (that of watching for signals made by the look-out frigates) with the greatest energy and perseverance, often remaining on deck nineteen hours out of the twenty four, with his attention constantly directed towards this one object. During the few hours which he spent in repose, his sleep was so profound, that no noise of an ordinary kind, however loud, would awake him; and it used to be a favourite amusement with his comrades, to try various experiments devised to test the soundness of his sleep. But if the word 'signal' was even whispered in his ear, he was instantly aroused, and fit for immediate duty.—The influence of habitual attention is shown as much in the effect produced by the cessation, as in that of the occurrence, of sensory impressions. Thus in the case of the naval officer aroused by the suspension of the measured tread of the watch over his head, the knowledge possessed during the waking state, that this suspension is either an act of negligence which requires notice, or indicates some unusual occurrence, doubtless augments the effect which the discontinuance of the sound would of itself produce.

688. It is not requisite, however, that the sound should be one habitually attended-to during the hours of watchfulness; for it is sufficient if it be one on which the *attention has been fixed* as that at which the slumberer is to arouse himself. Thus the medical man, even in his first profound sleep after a fatiguing day's work, is aroused by the first stroke of the clapper of his night-bell; and to those who are accustomed to rise every morning at the sound of an alarum-clock, the frequency and

regularity of the occurrence do not diminish, but rather increase, the readiness with which it produces its effect, provided that the warning be promptly obeyed. On this usually depends the efficiency of the awakening sound; if it be disregarded as a thing to which there is no occasion to give heed, it very soon ceases to produce any effect, the entire peal not being sufficient to awake the sleeper, whilst, on the other hand, the first stroke is enough to break the repose of him who is impressed with the effectual desire of profiting by the warning. And thus it may happen that, of two persons in the same room, either shall be at once aroused by a sound which produces no disturbance in the slumbers of the other. To this influence of previous impressions, whether habitual, or but once forcibly made, we are also to refer the spontaneous termination of the state of sleep at particular times, without any sensorial excitement from external impressions. Thus, many persons who are accustomed to rise at a particular hour, wake regularly at that hour, whether they have gone to rest early or late; so that the act of spontaneously awakening is no proof that the desirable amount of repose has been obtained. But what is more remarkable is, that many individuals have the power of determining, at the time of going to rest, the hour at which they shall rise, so as to awake from a profound sleep at the precise time fixed-upon. In others, however, the desire to rise at a particular hour only induces a state of restlessness throughout the night, destroying the soundness of the slumbers: the individual awakes many times in the night, with the belief that the hour is past, and very possibly oversleeps it after all, the system being worn-out by the need of repose.

689. The *Amount of Sleep* required by Man is affected by so many conditions, especially *age*, *temperament*, *habit*, and *previous exhaustion*, that no general rule can be laid-down on the subject.—The condition of the *fœtus in utero* may be regarded as one of continual slumber; the apparatus of animal life being completely secluded from all stimuli which could arouse it into activity, whilst the energy of the organic functions is entirely directed to the building-up of the fabric. On its first entrance into the world, the infant continues to pass the greater part of its time in slumber; and this is particularly to be noticed in cases of premature birth, the seven months' child seeming to awake only for the purpose of receiving food, and giving but little heed to external objects, whilst even the eight months' child is considerably less alive to sensory impressions than one born at the full time. The excess of activity of the *constructive* over the *destructive* operations, which characterizes the whole period of infancy, childhood, and adolescence (CHAP. XVIII.), requires that a larger proportion of the diurnal cycle shall be passed in sleep (during which the former may be carried-on without hindrance), than is requisite when adult age has been attained, the two sets of changes being then balanced; and the amount of sleep to which the system shows itself disposed, gradually diminishes from three-fourths to one-half, and from one half to one-third, or even to one-quarter, of the twenty-four hours. It is to be noticed that the sleep of children or young persons is not only longer than that of adults, but is also more profound. On the other hand, as age advances, and the bodily and mental activity of the waking state decreases, a smaller amount of sleep suffices; or, if the slumber be protracted, it is usually less deep and refreshing. It may be noticed, however,

that very old persons usually pass a large proportion of their time in sleep, or rather in a sort of heavy doze, especially after meals; as if, in consequence of the want of energy of their nutritive operations, a very long period of repose is necessary to repair the waste which takes place during their short period of activity.—In regard to the influence of *temperament*, it may be remarked that a plethoric habit of body, sustained by full diet, usually predisposes to sleep, provided that the digestive powers be in a vigorous condition; persons of this constitution frequently pass nine or ten hours in slumber, and maintain that they cannot be adequately refreshed by less. On the other hand, thin wiry people, in whom the 'nervous' temperament predominates, usually take comparatively little sleep, notwithstanding the greater activity of their nervous system when they are awake; but their slumber, while it lasts, is generally very deep. Persons of 'lymphatic' temperament, heavy passionless people, who may be said to live very slowly, are usually great sleepers; but this is rather because, through the dulness of their perceptions, they are less easily kept awake by sensorial or mental excitement, than because they really require a prolonged cessation of activity. As they are half asleep during the waking state, so would it appear that the constructive operations must be far from active while they are asleep, so little do they seem restored by their repose.—The amount of sleep, *cæteris paribus*, required by individuals, is very greatly influenced by *habit*; and, contrary to what we might anticipate, we find that the briefest sleepers have usually been men of the greatest mental activity. Thus Frederick the Great and John Hunter are said to have only required five hours' sleep out of the twenty-four; and General Elliot, celebrated for his defence of Gibraltar, is recorded not to have slept more than four hours out of the twenty-four. It may be doubted whether it would be possible for any one to sustain a life of vigorous exertion upon a smaller allowance than this; and the general fact is, that from six to eight hours of repose, out of every twenty-four, are required to keep the system of an adult in a state of healthful activity. The influence of habit may be brought to bear on the protraction, as well as on the abbreviation, of the usual period. Thus Quin, the celebrated actor, could slumber for twenty-four hours successively; and Dr Reid, the metaphysician, could take as much food, and afterwards as much sleep, as were sufficient for two days. It is needless to dwell upon the obvious fact, that, other things being equal, the amount of sleep required by man is proportional to the *amount of mental exertion* put forth during the waking hours, since this is an obvious result of what has been laid down as the cause of the demand for sleep. It may be remarked, however, that we must not measure the *amount* of sleep by its *duration* alone; since its *intensity* is a matter of equal importance. The light slumber which is disturbed by the slightest sounds, cannot be as renovating as the profound sopor of those whom no ordinary noise will awake.

580. There are certain states of the Encephalic centres, in which there is an *entire absence of Sleep*; and this may continue for many days, or even for weeks or months. Insomnia is, for instance, one of the characteristics of acute Mania, and may also exist in various forms of Monomania; it is usually, also, one of the symptoms of incipient meningeal inflammation; and it may constitute a specific disease in itself. In all these cases, however, the preponderance of the *destructive* processes over the *constructive*

manifests itself, sooner or later, in the exhaustion of the mental and bodily powers. Thus Mania, when prolonged or frequently recurring, subsides into Dementia; and, if it continue for any length of time, is sure to be followed by a great sense of wretchedness and prostration, frequently accompanied by continual restlessness. Such effects, too, in a less aggravated degree, result from habitual *deficiency* of sleep; whether this be due to emotional excitement, which keeps repose at bay, or to a voluntary determination to keep the intellect in activity. This is a very common occurrence among industrious students, who, with a laudable desire for distinction, allow themselves less than the needed quantum of repose. Headache, tension, heat, throbbing, and various other unpleasant sensations in the head, give warning that the brain is being overtasked; and if this warning be not taken, sleep, which it was at first difficult to resist, becomes even more difficult to obtain; a state of general restlessness and feverish excitement is induced; and if, in spite of this, the effort be continued, serious consequences, in the form of cerebral inflammation, apoplexy, paralysis, fever, insanity, or loss of mental power, more or less complete, are nearly certain to be induced. Some individuals can sustain such an effort much longer than others, but it is a great mistake to suppose that they are not equally injured by it; in fact, being possessed with the belief that they are not suffering from the exertion, they frequently protract it, until a sudden and complete prostration gives a fearful demonstration of the cumulative effects of the injurious course in which they have been persevering. Those, consequently, who are earlier forced to give-way, are frequently capable of accomplishing more in the end.—In regard to the degree of *protraction* of sleep which is consistent with a healthy state of the system in other respects, it is difficult to speak with certainty. Of the numerous well-authenticated instances on record,* in which sleep has been continuously prolonged for many days or even weeks, it is enough here to state that they cannot be regarded as examples of natural sleep; the state of such persons being more closely allied to hysteric coma. An unusual tendency to ordinary sleep generally indicates a congested state of the brain, tending to apoplexy; and it has been stated that apoplexy has been actually induced by the experimental attempt to ascertain how large a proportion of the diurnal cycle might be spent in sleep.—Thus, on either side, inattention to the dictates of Nature, in respect to the amount of sleep required for the renovation of the system, becomes a source of disease, and should therefore be carefully avoided.

691. *Dreaming.*—We have hitherto spoken of Sleep in its most complete or profound form; that is, the state of complete unconsciousness. But with the absence of consciousness of external things, there may be a state of mental activity, of which we are more or less distinctly cognizant at the time, and of which our subsequent remembrance in the waking state varies greatly in completeness. The chief peculiarity of this state of *dreaming* appears to be, that there is an entire suspension of Volitional control over the current of thought, which flows-on automatically, sometimes in a uniform, coherent order, but more commonly in a strangely-incongruous sequence. The former is most likely to occur, when the mind simply takes-up the train of thought on which it had

* Such, for example, as that of Samuel Chilton ("Phil. Trans.," 1694), and that of Mary Lyall ("Trans. of Roy Soc. of Edinb.," 1818).

been engaged during the waking-hours, not long previously; and it may even happen that, in consequence of the freedom from distraction resulting from the suspension of external influences, the Reasoning processes may thus be carried-on during sleep with unusual vigour and success, and the Imagination may develope new and harmonious forms of beauty.* The more general fact is, however, that there is an entire want of any ostensible coherence between the ideas which successively present themselves to the consciousness; and yet we are completely unaware of the incongruousness of the combinations which are thus formed. It has been well remarked that "nothing surprises us in dreams." All probabilities of 'time, place, and circumstance' are violated; the dead pass before us as if alive and well; even the sages of antiquity hold personal converse with us; our friends upon the antipodes are brought upon the scene, or we ourselves are conveyed thither, without the least perception of the intervening distance; and occurrences, such as in our waking state would excite the strongest emotions, may be contemplated without the slightest feeling of a painful or pleasurable nature. Facts and events long since forgotten in the waking state, and remaining only as latent impressions on the Cerebrum (§ 642), present themselves to the mind of the dreamer; and many instances have occurred, in which the subsequent retention of the knowledge thus re-acquired has led to most important results.† But one of the most remarkable of all the peculiarities in the state of dreaming, is the *rapidity* with which trains of thought pass through the mind; for a dream in which a long series of events has seemed to occur, and a multitude of images has been successively raised-up, has been often certainly known to have occupied only a few minutes, or even seconds, although whole years may seem to the dreamer to have elapsed. There would not appear, in truth, to be any limit to the amount of thought which may thus pass through the mind of the dreamer, in an interval so brief as to be scarcely capable of measurement; as is obvious from the fact, that a dream involving a long succession of supposed events, has often distinctly originated in a sound which has also awoke the sleeper, so that the whole must have passed during the almost inappreciable period of transition between the previous state of sleep and the full waking consciousness.‡ Hence it has been argued by some, that *all* our dreams really take place in the momentary passage between the states of

* Thus, Condorcet saw in his dreams the final steps of a difficult calculation which had puzzled him during the day; and Condillac tells us that, when engaged in his "Cours d'Etude," he frequently developed and finished a subject in his dreams, which he had broken-off before retiring to rest. Coleridge relates of himself, that his fragment "Kubla Khan" was composed during sleep, which had come upon him whilst reading the passage in "Purchas's Pilgrimage" on which the poetical description was founded, and was written down immediately on awaking, "the images rising up before him as things, with a parallel production of the correspondent expressions, without any sensation or consciousness of effort."

† See a number of such cases in Dr. Abercrombie's "Inquiries concerning the Intellectual Powers."

‡ The only phase of the waking state, in which any such intensely-rapid succession of thoughts presents itself, is that which is now well attested as a frequent occurrence, under circumstances in which there is imminent danger of death, especially by drowning; the whole previous life of the individual seeming to be presented instantaneously to his view, with its every important incident vividly impressed on his consciousness, just as if all were combined in a picture, the whole of which could be taken-in at a glance.

sleeping and waking; but such an idea is not consistent with the fact, that the course of a dream may often be traced, by observing the successive changes of expression in the countenance of the dreamer. It seems, however, that those dreams are most distinctly remembered in the waking state, which have passed through the mind during the transitional phase just alluded-to; whilst those which occur in a state more allied to Somnambulism, are more completely isolated from the ordinary consciousness.—There is a phase of the dreaming state, which is worthy of notice as marking another gradation between this and the vigilant state; that, namely, in which the dreamer has a consciousness that he is dreaming, being aware of the unreality of the images which present themselves before his mind. He may even make a voluntary and successful effort to prolong them if agreeable, or to dissipate them if unpleasing; thus evincing the possession of a certain degree of that directing power, the entire want of which is the characteristic of the true state of Dreaming.

692. But the sensibility to external impressions may not be entirely suspended in Dreaming; and it is curious that even where sensations are not recognized by the mind of the dreamer as proceeding from external objects, they may affect the course of its own thoughts; so that the character of the dreams may be in some degree predetermined by such an arrangement of sensory impressions as is likely to modify them. This is especially the case in regard to the dreamy state induced by certain narcotics, such as the Hachisch (a preparation of *Cannabis Indica*) employed for this purpose in the East (§ 702); for the emotional condition of the individual under its influence, is entirely under the control of external impressions; so that those who give themselves up to the intoxication of the *fantasia*, take care to withdraw themselves from everything which could give their delirium a tendency to melancholy, or excite in them anything else than feelings of pleasurable enjoyment.* Moreover, there are certain forms of ordinary Dreaming, in which the whole succession of thought and feeling (which is made manifest by the words occasionally uttered, or by the play of countenance, or by the more active movements of the dreamer) may be governed by external suggestion; as, for example, in the well known case of the officer who amused his friends by acting his dreams, during the expedition to Louisburgh, the course of these dreams being capable of direction by whispering into the sleeper's ear, especially if this was done by a friend with whose voice he was familiar.† Such forms of Dreaming constitute a transition to the state of Somnambulism.

693. *Somnambulism.*—The phenomena of Somnambulism are so various, that it is difficult to give any general definition that shall include the whole; but it is a condition which is common to all forms of this state, that the controlling power of the Will over the current of thought is entirely suspended, and that all the actions are directly prompted by the

* See the Author's article 'Sleep,' in the "Cyclop. of Anat. and Phys.," vol. iv., pp. 688 690, and Moreau "Du Hachisch et de l'Aliénation Mentale, Études Psychologiques," p. 67.

† This case is detailed by Dr. Abercrombie ("Inquiries concerning the Intellectual Powers," 5th Ed., p. 277,) on the authority of Dr. Gregory, to whom it was related by a gentleman who witnessed it. A case of a very similar nature, the subject of which was a medical student at Edinburgh, is related in Smellie's "Philosophy of Natural History."

ideas which possess the mind; and the differences chiefly arise out of the mode in which the succession of ideas is directed, this being in some cases a coherent sequence through the whole of which some one dominant impression may be traced, whilst in other instances it is more or less completely determinable by external suggestions. These two forms are thus parallel to the states of spontaneous Abstraction and artificial Reverie (Electro-Biology) respectively (§§ 671, 672), but differ from them both in this essential feature, that they occur in a state of consciousness so far distinct from the ordinary waking condition, as not to be connected with it by the ordinary link of Memory; and that although the course of thought in Somnambulism usually manifests the directing influence of previous habits, and the knowledge of persons and things possessed during the waking state may be readily brought before the mind, yet nothing which occurs during the state of Somnambulism is ever retraced spontaneously, or can be brought-back by an act of recollection. Impressions upon the nervous system, however, are sometimes left by strong emotional excitement, which give-rise to subsequent feelings of discomfort, of whose origin the individual is entirely unconscious.*—In the first of the phases just referred-to, a train of reasoning is often carried-out with remarkable clearness and correctness, and its results expressed in appropriate language, or otherwise acted-on. Thus, a mathematician may work-out a difficult problem, an orator may make a speech appropriate to the occasion on which he supposes himself to be called-up, or an author may compose and commit to writing poetry or prose, upon the subject which occupies his thoughts. But it is a frequent defect of the intellectual operations carried on in this condition, that, through the complete absorption of the attention by one set of considerations, no account is taken of others which ought to modify the conclusion; and this, although it may be palpably inconsistent with the teachings of ordinary experience, is not felt to be so, unless the latter should happen to present themselves unbidden to the thoughts.

694. The second of the phases above mentioned, which is especially seen in the *artificial* Somnambulism induced by the (so-called) *Mesmeric* process (§ 696), or by the fixed gaze at a near object (as practised by Mr. Braid under the name of *Hypnotism*), is essentially the same as that of the 'biological' condition, save in the different relation which they respectively bear to the waking state; for there is the same readiness to receive new impressions through the senses (the visual sense, however, being generally in abeyance), and the same want of persistence in any one train of ideas, the direction of the thoughts being entirely determined by the suggestions which are introduced from without. In either of these extreme forms of Somnambulism, and in the numerous intermediate phases which connect the two, the consciousness seems entirely given-up to the one impression which is operating upon it at the time; so that whilst the attention is exclusively directed upon any object, whether actually perceived through the senses, or brought suggestively before the mind by previous ideas, nothing else is felt. Thus there may be complete insensibility to bodily pain, the somnambulist's whole attention being given to what is passing in his mind; yet in an

* See a very curious example of this kind, which fell under the Author's own observation, narrated in the Article 'Sleep,' in the "Cyclop. of Anat. and Phys.," vol. iv. p. 693.

instant, by directing the attention to the organs of sense, the anæsthesia may be replaced by ordinary sensibility, or, by the fixation of the attention on any one class of sensations, these shall be perceived with most extraordinary acuteness, whilst there may be a state of complete insensibility as regards the rest.—Thus, the Author has witnessed a case in which such an exaltation of the sense of Smell was manifested, that the subject of it discovered without difficulty the owner of a glove placed in his hand, in an assembly of fifty or sixty persons; and in the same case, as in many others, there was a similar exaltation of the sense of Temperature. The exaltation of the Muscular Sense, by which various actions that ordinarily require the guidance of vision, are directed independently of it, is a phenomenon common to the 'mesmeric' with various other forms of artificial as well as of natural Somnambulism. The Author has repeatedly seen Mr. Braid's 'hypnotized' subjects write with the most perfect regularity, when an opaque screen was interposed between their eyes and the paper, the lines being equidistant and parallel; and it is not uncommon for the writer to carry back his pen or pencil to dot an *i* or cross a *t*, or make some other correction in a letter or word. Mr B. had one patient who would thus go back and correct with accuracy the writing on a whole page of note-paper; but if the paper was moved from the position it had previously occupied on the table, all the corrections were on the *wrong* points of the paper as regarded the *actual* place of the writing, though on the *right* points as regarded its *previous* place; sometimes, however, he would take a fresh departure, by feeling for the upper left-hand corner of the paper, and all his corrections were then made in their right positions, notwithstanding the displacement of the paper.—So, again, when the attention of the somnambulist is fixed upon a certain train of thought, whatever may be spoken in harmony with this is heard and appreciated; but what has no relation to it, or is in discordance with it, is entirely disregarded.

695. It is among the most curious of the numerous facts which Mr Braid's investigations upon artificial Somnambulism have brought to light, that the suggestions derived from the 'muscular sense' have a peculiar potency in determining the current of thought. For if the face, body, or limbs be brought into an attitude that is expressive of any particular emotion, or that corresponds with that in which it would be placed for the performance of any voluntary action, the corresponding mental state,—that is, either an Emotional condition affecting the general direction of the thoughts, or the Idea of a particular action,—is called-up in respondence to it. Thus, if the hand be placed upon the vertex, the Somnambulist will frequently, of his own accord, draw his body up to its fullest height, and throw his head slightly back; his countenance then assumes an expression of the most lofty pride, and the whole train of thought is obviously under the domination of this feeling, as is manifested by the replies which the individual makes to interrogatories, and by the tone and manner in which these are delivered. Where the first action does not of itself call-forth the rest, it is sufficient to straighten the legs and spine, and to throw the head somewhat back, to arouse the emotion, with its corresponding manifestation, in its full intensity. If, during the most complete domination of this emotion

the head be bent forwards and the body and limbs be gently flexed, the most profound humility then takes its place. So, again, if the angles of the mouth be gently separated from one another, as in laughter, a hilarious disposition is immediately generated, and this may be made to give place to moroseness, by drawing the eyebrows towards each other and downwards upon the nose, as in frowning.* So, again, if the hand be raised above the head, and the fingers be flexed upon the palm, the idea of climbing, swinging, or pulling at a rope is called-up in such as have been used to such kinds of exertion; if, on the other hand, the fingers be flexed when the arm is hanging-down at the side, the idea suggested is that of lifting a weight; and if the same flexure be made when the arm is advanced forwards in the position of striking a blow, the idea of fighting is at once aroused, and the Somnambulist is very apt to put it into immediate execution.†

696. *Mesmerism.*—It appears to the Author that the time has now come, when a tolerably definite opinion may be formed regarding a large number of the phenomena commonly included under the term 'Mesmerism.' Notwithstanding the exposures of various pretenders, which have taken-place from time to time, there remains a considerable mass of phenomena which cannot be so readily disposed-of, and which can put-forward as just a title to the attention of the scientific Physiologist, as that which is possessed by any other class of well-ascertained facts. Passing-over, for the present, the inquiry into the manner in which these effects may be induced, the Author may briefly enumerate the principal phenomena which he regards as having been veritably presented in a sufficient number of instances, to entitle them to be considered as genuine and regular manifestations of the peculiar bodily and mental condition under discussion:—1. A state of complete *Coma* or perfect insensibility, analogous in its mode of access and departure to that which is known as the 'Hysteric Coma,' and (like it) usually distinguishable from the coma of Cerebral oppression by a constant twinkling movement of the eyelids. In this condition, severe surgical operations may be performed, without any consciousness on the part of the patient, and it is not unfrequently found that the state of torpor extends from the Cerebrum and Sensory Ganglia to the Medulla Oblongata, so that the respiratory movements become seriously interfered-with, and a state of partial asphyxia supervenes.—2. A state of *Somnambulism* or Sleep-waking, which may present all the varieties of the natural Somnambulism, from a very

* The Author has not only repeatedly witnessed all these effects, as produced by Mr. Braid upon 'hypnotized' subjects, of whom several had never been previously in that condition, and had no idea whatever of what was expected from them, but he has been assured by a most intelligent medical friend, who has paid special attention to the psychological part of this inquiry, that having subjected himself to Mr. Braid's practice, and having been only partially thrown into the 'hypnotic' state (in fact, 'biologized'), he distinctly remembers everything that was done, and can retrace the uncontrollable effect upon his emotional state, which was produced by this management of his muscular apparatus.

† On one occasion on which the Author witnessed this result, a violent blow was struck, which chanced to alight upon a second somnambulist within reach; *his* combativeness being thereby excited, the two closed, and began to belabour one another with such energy, that they were with difficulty separated. Although their passions were at the moment so strongly excited, that even when separated they continued to utter furious denunciations against each other, yet a little discreet manipulation of their muscles soon calmed them and restored them to perfect good-humour.

limited awakening of the mental powers, to the state of complete Double Consciousness, in which the individual manifests all the ordinary powers of his mind, but remembers nothing of what has passed when restored to his natural waking state. This state of Somnambulism, in the form which it commonly takes, is characterised by the facility with which the thoughts are directed into any channel which the observer may desire, by the principle of 'suggestion,' and by the want of power on the part of the Somnambulist, to apply the teachings of ordinary experience to the correction of the erroneous ideas which are thus made to occupy the mind. In these particulars, this condition closely corresponds with that of the artificial Somnambulism or 'hypnotism' of Mr. Braid (§ 694); and the only peculiarity in its phenomena which can be regarded as at all essential, consists in the special relation which is affirmed to exist between the mesmerizer and his 'subject.' Now in regard to the existence of this *rapport*, it is specially note-worthy, that it was not discovered until long after the practice of Mesmerism had come into vogue, having been unknown to Mesmer himself and his immediate disciples, and that its phenomena have only acquired constancy and fixity, in proportion as its (supposed) laws have been announced and received as established. The history of Mesmerism, candidly and philosophically analysed, affords abundant evidence in proof of this position; but the best guarantee of its truth is drawn from the results obtained from the numerous Mesmerizers, who have begun to experiment for themselves without any knowledge of what they were to expect, and who have produced a great variety of remarkable phenomena, without having ever discovered this *rapport*; and yet have obtained immediate evidence of it, when once the idea has been put into their own minds, and thence into those of their 'subjects.' It is quite easy to understand, that if the mind of the 'subject' be so yielded-up to that of the mesmerizer, as to receive and act-upon any impression which the latter forces upon or even suggests to it, the notion of this peculiar relation is as easily communicable as any other, and may exert a complete domination over the 'subject,' through the whole of the sleep-waking state. Thus the commands or suggestions of the mesmerizer meet with a response which those of no other individual may produce; in fact, the latter usually seem to be unheard by the somnambule, simply because they are not related to the dominant impression,—a phenomenon of which the experience of natural somnambulism is continually presenting examples (§ 694). Further, it being a fact that individuals of what may be termed the susceptible constitution, have brought themselves, by the habit of obedience, into complete subjection to the expressed or understood will of some other party, even in the waking state, without any mesmeric influence whatever, it is not at all difficult to understand how such a habit of attending to the operator, and to him alone, should be peculiarly developed in the state of Somnambulism, in which the mind seems to have lost its self acting power, and to be the passive recipient of external impressions. And the same explanation applies to the other phenomena of this *rapport*; such as its establishment with any bystander, by his joining hands with the mesmerizer and the somnambule; for, as already shown (§ 694), it is quite sufficient that the somnambule should be previously possessed with the idea that this new voice will thus be audible to her, and that she must

obey its behests, for it to produce all the same effects upon her as that of the mesmerizer had previously done. In all the *successful* experiments of this kind which the Author has seen, this previous idea *was* entertained, both by mesmerizer and somnambule; but in by far the larger proportion of cases which have fallen under his notice, and especially when the subjects of them were not *habituées* of the mesmeric *séances*, the phenomena of this class could not be made to show themselves, the consciousness of the somnambule not being limited to the mesmerizer or to those *en rapport* with him, but being equally extended to all around her. 3. A frequent phenomenon of this condition, and one which has its parallel in natural Somnambulism (§ 694), is a remarkable *Exaltation of one or more of the Senses*, so that the individual becomes susceptible of influences which, in his natural condition, would not be in the least perceived. To this exaltation may fairly be attributed a great number of the phenomena, which have been supposed to indicate a peculiar and mysterious influence exerted by the Mesmerizer over his 'subject,' since the latter will be far more receptive of 'suggesting' impressions, than an ordinary bystander would suppose possible. And it is to be borne in mind that the concentration of the attention upon these may often give them a far greater significance to the individual, than they possess for others; this, it seems likely, is especially the case in regard to tones of voice, emphasis of manner, &c., when questions are propounded.—4. The *Muscular apparatus* may also be excited to action in unusual modes, and with unusual energy. Notwithstanding the fallacy of many of the cases of Cataleptic rigidity which have been publicly exhibited, the Author is satisfied, from investigations privately made, of the possibility of artificially inducing this condition. A slight irritation of the muscles themselves, or of the skin which covers them,—as by drawing the points of the fingers over them, or even wafting currents of air over the surface,—is sufficient to excite the tonic muscular contraction, which may continue in sufficient force to suspend a considerable weight, for a longer period than it could be kept up by any conceivable effort of voluntary power. But these are phenomena which are quite as well displayed in artificial Somnambulism induced in other ways, as they are in the 'mesmeric' state; and do not afford, therefore, any more than the preceding, the slightest indication of the speciality of the latter, or the least proof of any extraneous influence exerted over the 'subject.'—5. Various effects, it is asserted, may be produced upon the *Organic Functions* by 'Mesmeric' influence; and it is on account of this agency, that it claims to be admitted as a directly-curative agent. It will be hereafter shown, however, that effects of a precisely similar kind may be produced in other forms of Artificial Somnambulism, by simply fixing the attention on the part, and that the same may be done, even in the ordinary waking state, in certain subjects who can be worked-up to the requisite pitch of confident expectation. (See § 837.)*

* The above are the principal phenomena of the 'Mesmeric' state, in regard to which the Author feels his mind made-up. He does not see why any discredit should be attached to them, since they correspond in all essential particulars with those of states, which naturally or spontaneously occur in many individuals, and which he has had opportunities of personally observing, in cases in which the well known characters of the parties placed them above suspicion. When the facility with which the mind of the Somnambulist is played-on by suggestions (conveyed either in language, or through other sensations

which excite associated ideas), and the absence of the corrective power ordinarily supplied by past experience, are duly kept in view, many of the supposed 'higher phenomena' of Mesmerism may be accounted for, without regarding the patient on the one hand as possessed of extraordinary powers of divination, or on the other as practising a deception. Thus, bearing in mind that Somnambulism is an acted dream, the course of which is governed by external impressions, it is easy to understand how the subject of it may be directed by 'leading questions' to enter buildings which he has never seen, and to describe scenes which he has never witnessed, without any intentional deceit. The love of the marvellous so strongly possessed by many of the witnesses of such exhibitions, prompts them to grasp at and to exaggerate the coincidences in all such performances, and to neglect the failures; and hence reports are given to the public, which, when the real truth of them is known, prove to have been the results of a series of guesses, the correctness of which is in direct relation to the amount of guidance afforded by the questions themselves. In like manner, the manifestations of the excitement of the 'phrenological organs' seem to depend upon the conveyance of a suggestion to the patient, either through his knowledge of their supposed seat, or through the anticipations expressed by the by-standers. Many instances are recorded, in which the intention has been stated of exciting one organ, whilst the finger has been placed upon or pointed at another; and the resulting manifestation has always been that which would flow from the former. It does not hence follow that intentional deception is being practised by the Somnambulist; since the condition of mind already referred-to, causes it to respond to the suggestion which is most strongly conveyed to it.

In regard to the alleged powers which are said to be possessed by many Somnambulists, of reading with the eyes completely covered, or of discerning words enclosed in opaque boxes, or of giving an account of what is taking-place at a distance, all coming under the general term *Clairvoyance*, the Author need only here express his conviction that no case of this description has ever stood the test of a searching investigation.

With respect to the modes in which the 'Mesmeric' Somnambulism is induced, it appears to him that they are all referable to those states of *monotony of sensory impressions*, and of *expectation*, to which reference has been already made, as among the most potent of the predisposing causes of conditions allied to Sleep (§§ 682, 685). It is asserted by Mesmerizers, that they can induce the 'Mesmeric' state from a distance, without the least consciousness on the part of their 'subjects' that any influence is being exerted on them,—an assertion, which, if true, would go far to establish the existence of a force altogether *sui generis*, capable of being transmitted from one individual to another. Here, however, as in regard to the 'higher phenomena' last adverted to, the Author feels compelled to state that no evidence of an affirmative kind has yet been adduced, which can be in the least degree satisfactory to a scientific enquirer, who duly appreciates all the sources of fallacy to which these occurrences are open. Among these, the state of expectation on the part of the 'subject' is the most important; since this has been shown, by repeated experiments, to be of itself quite sufficient to induce the state, when the 'subject' has been led to entertain it; whilst, if it be *altogether* wanting, the most powerful Mesmeric influence, so far as the Author's personal knowledge extends (and on this subject, he must be excused for trusting rather to the results of his own investigations, than to the statements of other individuals, however trustworthy on ordinary matters), has always failed. A very striking instance of this kind is contained in the "Brit. and For. Med. Rev.," vol. xix. p. 478, in an Article to which the Author may refer us on the whole expressing (although not written by himself) his own opinions on this curious and interesting subject, strengthened as these are by much subsequent inquiry into the phenomena of 'Hypnotism' and 'Electro Biology,' the attentive and scientific study of which will tend, he feels assured, to eliminate the true from the false in Mesmerism, more effectually than any other method of procedure. Much has been done by the enquiries of Mr. Braid of Manchester, who discovered the 'hypnotic' mode of inducing artificial Somnambulism, and who has carefully studied the phenomena of the hypnotic state; and the Author feels it due to that gentleman further to mention, that very soon after the publication of the first edition of Baron Reichenbach's researches on Odyle, Mr. Braid discovered their true explanation, and exhibited to the Author many of the 'odylic' phenomena, as the results of *suggestion* in certain individuals, whom he had discovered to have the power of voluntarily inducing a state of Abstraction or artificial reverie, closely corresponding to what is now termed the Electro-Biological condition.

On the whole subject of Sleep and its allied states, as well as on that of Cerebral Physiology generally, the Author would strongly recommend his readers to study Sir H. Holland's "Chapters on Mental Physiology;" in which they will find a most valuable and

[illegible]gestive collection of facts and doctrines, based upon an extended practical experience, and brought to bear particularly upon the more difficult and recondite portions of the [illegible]. A fuller analysis of the phenomena of Somnambulism (natural and artificial), [illegible]ism, and other allied states, will be found in the "Quarterly Review," Sept., [illegible].

8. *General Recapitulation, and Pathological Applications.*

In summing-up the views which have been propounded in this Chapter, with regard to the normal functions of the Nervous System, and in applying these to the elucidation of its principal modes of abnormal activity, it will be advantageous to follow the reverse order to that which has been previously adopted, and to proceed from above downwards, instead of from below upwards.

697. The entire *Nervous System*, like other organs of the body, possesses vital endowments peculiar to itself, in virtue of which it tends to respond in a determinate manner to impressions made upon it; the properties of its several parts being distinguished by the *modus operandi* of impressions upon each respectively. In so far, then, as any part of the Nervous System merely reacts upon impressions which are made upon it, we must regard its operations as *automatic;* and this as much when they give rise to Psychical changes, as when they manifest themselves in evoking Muscular movements, or in modifying the processes of Nutrition and Secretion.—But the automatic actions of most parts of the Nervous System are subject, more or less completely, to the domination of the *Will*, a power which is purely Psychical, and of which we know nothing but what we learn from our own direct consciousness of its exercise. The power of the Will is the *greatest* over the automatic actions of the *highest* portions of the Nervous Centres, which are concerned in *psychical* changes; whilst it has the *least* influence over the automatic actions of those *lower* centres, which minister solely to the functions of the *bodily organism.*

698. *Normal Modes of Cerebral Activity.*—The *Cerebrum* is the material organ, through whose instrumentality all the processes of Thought are carried on. These processes are first called into activity by impressions conveyed to the vesicular matter of the Cerebral surface, by *ascending* nerve-fibres which proceed to it from the Sensory Ganglia; and the influence of that activity is re-transmitted to the Sensory Ganglia, by a converse set of *descending* fibres.* There is much reason to consider that, until such re-transmission has taken place, the *consciousness* is not so affected by Cerebral changes, as to give to the results of these changes a *psychical* character; for the central Sensorium appears to stand in precisely the same anatomical and physiological relation to the vesicular matter of the Cerebral surface, that it does to the vesicular matter of the Retina or other peripheral expansions of the Sensory nerves; and there is strong analogical ground for the belief, that the process by which the Mind is rendered cognizant of changes in the Cerebrum, is performed by the same

* The structural distinctness of these two sets of fibres must be admitted to be hypothetical; and it is improbable that any anatomical evidence can ever be attained, by which the hypothesis may be established. But all the analogy of the afferent and efferent fibres throughout the body, is opposed to the idea that the same fibres can serve both purposes. Whatever may be thought of their structural distinctness, however, there can be no reasonable doubt of the transmission of nerve-force in the two directions above indicated.

instrumentality as that by which it is made acquainted with impressions on the Organs of Sense. And this view is confirmed by the fact, that automatic changes may take place in the Cerebrum without any consciousness on our own parts; the results of which changes, when we at last become conscious of them, correspond with those that we ordinarily attain by processes whose successive steps excite as many successive states of consciousness.—These Cerebral changes, then, acting downwards upon the Sensorium, give rise to those affections of our consciousness, which we designate as *Mental Processes*. These processes,—called into activity by Sensorial impressions,—ranging from the simplest act of Ideation to the highest operations of Intellectual power,—consisting also in the play of Fancy and Imagination, and including an essential part of those active states known as Passions, Emotions, Moral Feelings, Sentiments, &c.,—must be regarded as essentially *automatic* in their nature, and as the manifestations of the 'reflex' activity of the Cerebrum; since we have abundant evidence that they can take-place without any self-direction on the part of the individual, who, whilst his Will is in abeyance, is in the condition of an animal entirely governed by Instinct. There is, however, far less of uniformity in these 'reflex actions' of the Cerebrum, than we observe in those reflex actions of other parts of the Nervous System, which give-rise to the movements ordinarily designated as 'instinctive;' this diversity seems partly attributable to differences in the *original* constitution of different individuals; but it is certainly due in great part to differences in the *acquired* constitution of the organ, arising out of the mode in which it has been habitually exercised,—this being dependent, on the one hand, on the circumstances in which the individual has been placed, and, on the other, on the use he has made of his Will.

699. When the power of the *Will* has been duly cultivated, it acquires so complete a domination over the 'automatic' actions of the Cerebrum, that it can regulate the course of Thought and the degree of Emotional excitement; intensifying some of these actions, and repressing others, by determinate efforts directed with that special purpose. Its power is so far limited, however, that it can only *select* from the objects which spontaneously present themselves to the consciousness, those which it desires to retain and employ, and has no direct power of bringing before the mind any object not actually present to it. Hence it is, that, whilst we have an almost unlimited power of turning to the best account the endowments we possess, by strengthening our Intellectual powers, expanding our higher Emotional tendencies, and bringing the lower Propensities under wholesome restraint, we cannot, by any effort of the Will, introduce *new* elements into our psychical nature.

700. The power of the Cerebrum to call-forth Muscular movements, is entirely exerted through the intermediation of the Cranio-Spinal Axis upon which it is superimposed; no motor fibres directly issuing from the Cerebrum itself. These movements, when directly determined by the Will, may be designated as *Volitional;* when they are involuntarily excited by states of passion, feeling, &c., of which they are the external expressions, they are distinguished as *Emotional:* and when they are prompted, in the absence of any volitional exertion, by the Idea which may for the time engross the consciousness, they may be termed *Ideational.* In each case, the nerve-force transmitted downwards from the Cerebrum

appears to produce the very same state of activity in the Sensori motor apparatus, as that which may be directly excited in it by impressions transmitted from the Organs of Sense; and thus the same instrumentality serves for all classes of movements, Voluntary and Involuntary, the difference in their character being solely referable to the diversity of their primal source.

701. *Abnormal Modes of Cerebral Activity.*—The Cerebrum being the instrument of all psychical activity, we must regard its action as disordered in every state in which that activity is perverted. The first degree of departure from the normal state, is usually shown in the want of Volitional control over the sequence of thought; and this may exist merely to the extent of giving the reflex power of the organ too great a predominance, so that trains of ideas and states of feeling succeed each other automatically, and all the actions of the individual are simply the expressions of these. Such is the mental state which exists in *Reverie* and in *Somnambulism*, natural or induced, the principal varieties in these states being traceable to the relative degree of influence of ideas already fixed in the mind, and of external suggestions, in determining the course of thought. It is to be remarked, however, in regard to these conditions, that they are generally characterized by a somewhat inactive state of the Cerebrum, so that the changes in the state of consciousness are not rapid, though such as do occur are coherent.* In *Dreaming*, *Delirium*, and the artificial delirium of *Intoxication*, on the other hand, with a like absence of the directing and restraining power of the Will, there is a greater and more irregular activity in the Cerebral operations; the ideas presenting themselves in far more rapid succession, and possessing a less perfect mutual coherence.

702. Very nearly allied to Dreaming and Somnambulism, are the states of *Delirium* and of *Mania*, which graduate almost imperceptibly one into the other; being chiefly distinguished by the degree and kind of excitement which they respectively exhibit, and by the nature of the bodily states with which they are connected. The loss of Voluntary control over the current of thought, is the primary element of both these conditions; and the gradual weakening of this may be frequently traced, when the transition from the normal state is not so rapid as to prevent its various steps from being watched. The *artificial delirium* produced by *Intoxicating agents*, affords peculiar facilities for this kind of observation; and among these agents, there is none whose operation is so interesting in this respect as Hachisch. The first effect of a dose of this substance, as described by M. Moreau (Op. cit.), is commonly to produce a moderate exhilaration of the feelings, and an unusual activity of the intellectual powers; but this activity gradually frees itself from the control of the Will. The individual feels himself incapable of fixing his attention upon any subject; his thoughts being continually drawn off by a succession of ideas which force themselves (as it were) into his mind,

* In most forms of induced Somnambulism, it appears as if the mental activity is only sustained by external prompting, all *spontaneous* activity being suspended, for the 'subject' continually relapses into a state of unconsciousness, and does not pass from one topic to another, unless induced to do so by 'leading questions.' In some cases of this kind, however, as well as in all those forms of natural Somnambulism in which the individual acts on the spontaneous promptings of his own thoughts, the mental state is one of continuous activity; but it is obvious that its operations are slow, and are very limited in their nature.

without his being in the least able to trace their origin. These speedily occupy his attention, and present themselves in strange combinations, so as to produce the most fantastic and impossible creations. By a strong effort of volition, however, the original thread of the ideas may be recovered, and the interlopers driven away. These 'lucid intervals' successively become of shorter and shorter duration, and can be less frequently procured by a voluntary effort; for the internal tempest becomes more and more violent, the torrent of (apparently) disconnected ideas increases in vehemence, so as completely to arrest the attention, and the mind is at last entirely given-up to it, and is at the same time withdrawn from the perceptive consciousness of external things, although as already pointed-out (§ 692), it is by no means removed from the influence of sensory impressions. The succession of ideas has at first less of incoherence than in ordinary dreaming, the ideal events not departing so widely from possible realities; and the disorder of the mind is primarily manifested in errors of perception, in false convictions, or in the predominance of one or more extravagant notions. These false ideas are generally not altogether of an imaginary character, but are originally called into existence by external impressions, these being erroneously interpreted through the disordered action of the perceptive faculty; thus, for example, among the most common perversions are those relating to time and space, minutes seeming hours, hours being prolonged into years, and all idea of time being at last obliterated, so that past and present are confounded together as in ordinary dreaming; whilst in like manner, streets may appear of an interminable length, the people at the other end seeming to be at a vast distance; for the mind has a tendency to *exaggerate* every impression made upon the consciousness, especially those which affect the emotional state. The effect of a full dose, however, is at last to produce the complete withdrawal of the mind from the contemplation of external things, and entirely to suspend the action of the Will over the current of thought; and the condition then comes to be nearly the same as that of ordinary Dreaming, the chief difference consisting in the readiness with which the emotions may be excited in those who are under the influence of the Hachisch, and in the degree in which their course of thought is amenable to external influences.

703. The following concise and faithful description of the ordinary *Delirium of disease*, will show how completely it corresponds in all its essential characters with that which is induced by the introduction of intoxicating agents into the blood. "In its highest degree it is a complete disturbance of the intellectual actions; the thoughts are not inactive, but rather far more active than in health; they are uncontrolled, and wander from one subject to another with extraordinary rapidity; or, taking up one single subject, they twist and turn it in every way and shape, with endless and innumerable repetitions. The thinking faculty seems to have escaped from all control and restraint, and thought after thought is engendered without any power of the patient to direct and regulate them. Sometimes they succeed each other with such velocity, that all power of perception is destroyed, and the mind, wholly engrossed with this rapid development of thoughts, is unable to perceive impressions made upon the senses; the patient goes-on unceasingly raving, apparently unconscious of what is taking-place around him; or it may be, that his

senses have become more acute, and that every word from a bystander, or every object presented to his vision, will become the nucleus of a new train of thought; and, moreover, such may be the exaltation of his sensual perception, that subjective phenomena will arise in connection with each sense, and the patient fancies he hears voices or other sounds, whilst ocular spectra in various forms and shapes appear before his eyes and excite further rhapsodies of thought."* It must be remarked that there is usually a greater disorder of the perceptive faculty in Delirium, than in ordinary Dreaming; for in the former condition, the erroneous images are more vividly conceived of as having an existence external to the mind, than they are in the latter; the illusory visual and auditory perceptions having all the force of reality, and often appearing to be the original *sources* of ideas, instead of (as seems to be rather the case in dreaming) their *products*.† This peculiarity probably depends upon a primary affection of the Sensorial centres by the morbid agent (§ 716).

704. The more active forms of Delirium pass by almost imperceptible gradations into the state of *Mania*, which is usually characterized by the combination of complete derangement of the intellectual powers, with passionate excitement upon every point which in the least degree affects the feelings. There is, however, a considerable amount of variety in the phases of Mania, depending upon differences in the relative degree of *intellectual* and of *emotional* disturbance. For there may be such a derangement of the former, as gives rise to complete incoherence in the succession of ideas, so that the reasoning power is altogether suspended; and yet there may be at the same time an entire absence of emotional excitement, so that the condition of the mind is closely allied to that of dreaming or of rambling delirium. On the other hand, the intellectual powers may be themselves but little disturbed, the trains of thought being coherent, and

* See Dr. Todd's 'Lumleian Lectures, on the Pathology and Treatment of Delirium and Coma,' in the "Medical Gazette," 1850, vol. xlv. p. 703. A circumstance was mentioned to the Author, whilst he was a student at Edinburgh, which remarkably illustrates the influence of suggestions derived from external sources, in determining the current of thought. During an epidemic of Fever which had occurred some time previously, and in which an active delirium had been a common symptom, it was observed that many of the patients of one particular physician were possessed by a strong tendency to throw themselves out of the window, whilst no such tendency presented itself in unusual frequency in the practice of others. The Author's informant, himself a distinguished Professor in the University, explained this tendency by what had occurred within his own knowledge, as follows:—His friend and colleague, Dr. A., was attending a patient, Mr. B., who seems to have been the first to make the attempt in question; impressed with the necessity of taking due precautions, Dr. A. then visited Dr. C., *in whose hearing* he gave directions to have the windows properly secured, as Mr. B. had attempted to throw himself out. Now Dr. C. distinctly remembers, that although he had not previously experienced any such desire, it came upon him with great urgency as soon as ever the idea was thus suggested to him; his mind being just in that state of incipient delirium, which is marked by the temporary dominance of some one idea, and by the want of voluntary power to withdraw the attention from it. And he deemed it probable that, as Dr. A. went on to Mr. D., Dr. E., &c., and gave similar directions, a like desire would be excited in the minds of all those who might happen to be in the same impressible condition.

† In true Dreaming, the sensational consciousness is entirely closed to the outward world; and all the images which we may believe we see, or the sounds that we fancy ourselves to hear, seem to result from changes in the Sensorium excited by Cerebral influence; but in Delirium there is an evidently disordered action of the Sensorium itself, of which spectral illusions and other 'subjective sensations' are the manifestation. This is particularly obvious in that form of Delirium which is known as *delirium tremens*.

the reasoning processes correctly performed; but there may be such a state of general emotional excitability, that nothing is *felt* as it should be, and the most violent passion may be aroused and sustained by the most trivial incidents, or by the wrong ideas which are formed by the mind as a consequence of their misinterpretation (§ 623). Between these two opposite states, and that in which the disturbance affects at the same time the intellectual and the emotional part of the Mental nature, there is a complete succession of transitional links; but, under all phases of this condition (these often passing into each other in the same individual), there is one constant element, namely, the deficiency of Volitional control over the succession of thought. This deficiency appears to be a primary element in those forms which essentially consist in Intellectual disturbance; whilst in those of which Emotional excitement is the prominent feature, it seems rather to result from the overpowering mastery that is exercised over the Will, by the states of uncontrollable passion which succeed each other with little or no interval. It seems probable, however, from the phenomena of Intoxication (§ 702), that the very same agency which is the cause of the undue Emotional excitability, also tends to produce an absolute diminution in the power of Volitional control.

705. From the state of Mania, we naturally pass to those more persistent forms of *Insanity*, in which there is some settled disorder in the action of the Mind. Although this may arise from the perversion of any part of the psychical nature, yet a partial or complete deficiency in the Volitional control over the current of thought, and consequently over the actions which are the expressions of it, seems to be a characteristic feature of every form of Insanity, and is frequently its first manifestation; and it is this, which, *in so far as it exists*, ought to be considered as rendering the individual irresponsible for his conduct. But with this is associated an excessive, deficient, or perverted activity of some one or more of the automatic tendencies; and hence Insanity must be regarded to that extent as consisting in a disordered action of the Cerebrum. This may be traced to a great variety of causes, which may be classified in different ways, according as we take their *own nature* or their *modus operandi* as the basis of our arrangement. Thus it is unquestionable that in a large proportion of cases of settled Insanity, there is an impairment of the due *Nutrition* of the Cerebrum; and this, which is often an hereditary defect, may arise *de novo*, like abnormal changes in the nutrition of other parts (CHAP. VIII.), from deficiency or perversion in the formative power of the tissue, or from an imperfect supply or from an altered character of its pabulum. Of the influence of deficient or perverted formative power in the tissue, we have examples in the Insanity resulting from mechanical injuries of the brain, and from excessive "wear" of the organ by forced activity. Of the effects of deterioration in the character of the blood, we have illustrations in the Insanity that is often linked-on with constitutional diseases of which such deterioration is a marked feature, and in that which is so frequent a consequence of habitual excess in the use of Alcoholic liquors. These conditions may exist in combination;* and it is, probably, by such a combination, that many

* Thus *Delirium tremens*, which may be regarded as a form of temporary Insanity, essentially consisting in perverted and imperfect nutrition of the Cerebrum, seems ordinarily to depend conjointly upon the excessive and irregular activity to which the organ

of the 'moral causes' of Insanity operate. For there can be little doubt that Emotional excitement, from its immediate relation to Nerve-force (§ 624), has a direct influence on the formative capacity of the Cerebrum; whilst, on the other hand, we know that it has so great an influence over the Organic functions, that it can produce very decided alterations in the condition of the Blood (CHAP. XV). But without any serious perversion of the *nutrition* of the Cerebrum, its *action* may be disturbed, either by the presence of some toxic agent in the Blood, or by functional disturbance in other parts of the Nervous system. The delirium of Intoxication is, whilst it lasts, a true Insanity; and it ceases because the poison is eliminated from the circulation. But there are many cases in which there is a continual production of a poison within the system, which deranges the normal train of mental action so long as the blood is tainted by it; the indication of treatment is here obviously to check this production, and to depurate the blood; and when this has been effectually accomplished, the healthy action of the Brain is immediately restored, which would not have been the case if its nutrition had been seriously impaired. Most persons have experienced the extreme depression of spirits and incapacity for mental exertion, which are consequent upon certain derangements of the digestive function, and especially upon disorder of the biliary apparatus; and it is unquestionable that many forms of Insanity, in which extreme dejection is a prominent symptom, but which may also include intellectual delusions, are solely dependent upon this cause. The functional disturbance of the Cerebrum induced by the irregular action of other parts of the Nervous System, is a part of the Etiology of Insanity which has been as yet but very little attended-to, but which deserves a careful study. Numerous examples of it are furnished by certain peculiar forms of disordered Mental action, which are connected with 'hysterical' states of the female system, especially mutability and irritability of temper and disposition to deceit,* but we are probably also to refer to this cause, in part at least, those very distressing states of mind, which arise out of disorders in the sexual apparatus of the male, or even from irritation of neighbouring parts.†—It frequently happens that agencies of both classes contribute to the result; some long-continued defect of nutrition (very often arising from hereditary constitution) serving as the 'predisposing cause,' whilst violent mental emotion, or depravation of the blood by noxious matter of some kind, acts as the 'exciting cause;' the two conjointly producing that effect, which neither would singly have brought-about.

706. It is chiefly (but not solely) in those cases in which the Cerebral

has been previously forced, and on the alteration of the normal character of the Blood produced by the habitual presence of Alcohol in its current; but it is well known that Delirium Tremens *may* occur as the result of other agencies that primarily depress the nutritive powers without perverting the blood, such as excessive depletion, the shock of severe injuries, or extreme cold. In either case, however, the indications of treatment are the same; namely, to induce sleep, whereby the irregular activity of the organ may be completetely suspended, and its due nutrition restored; and to correct what may be faulty in the condition of the blood.

* See Dr Laycock's "Treatise on the Nervous Diseases of Women," in which these *sympathies* are fully dwelt on.

† See M. Lallemand's "Treatise on Spermatorrhœa," translated by Mr McDougal.—In some of the cases recorded by M. Lallemand, the most extreme mental depression was engendered by the presence of ascarides in the rectum!

power has been weakened by a succession of attacks of Mania, Epilepsy, or some other disorder which consists in a perverted action of the whole organ, that we find the *Intellectual* powers specially and permanently disordered, the succession of thought becoming incoherent, and the perception of those relations of ideas on which all reasoning processes depend, being more or less completely obscured. The failure usually shows itself *first* in the power of Volitional direction, and especially in the faculty of Recollection; in proportion as the mind is unable to bring the results of past experience to bear on its present operations, do these lose their connectedness and consistency; and at last all the ordinary links of association appear to be severed, and (as in the most incoherent kinds of Dreaming) the succession of thoughts cannot be accounted-for on any known principles of psychical action. All this may occur with or without Emotional excitement; not unfrequently the latter occurs in paroxysms, which interrupt the otherwise tranquil life of the subjects of this form of Insanity; and it is not at all incompatible with this condition, that there should be a special excitability upon some one point, which, owing to the annihilation of the Volitional controlling power, acquires a temporary predominance whenever it is called into play. It is the general characteristic, however, of this form of Insanity, that there are no *settled* delusions; the mind not being disposed to dwell long upon any one topic, but wandering-off in a rambling manner, so as speedily to lose all trace of the starting-point. Such patients are unable to recollect what passed through their thoughts but a few minutes previously; if any object of desire be placed before them, which it requires a consistent reasoning process to attain, they are utterly unable to carry this through, and the direction of their desires is perpetually varying, and may be readily altered by external suggestion. Cases of Intellectual Insanity, depending (as this form of the disease usually does) upon structural disorder of the Cerebrum, are less amenable to treatment than are those of the other forms presently to be described; and their tendency is usually towards complete fatuity.

707. There may, however, be no primary disorder of the Intellectual faculties; and the Insanity may essentially consist in a tendency to disordered *Emotional* excitement; which affects the course of thought, and consequently of action, without disturbing the reasoning processes in any other way than by supplying wrong materials to them. Now the emotional disturbance may be either *general* or *special;* that is, there may be a derangement of feeling upon almost every subject, matters previously indifferent becoming invested with strong pleasurable or painful interest, things which were previously repulsive being greedily sought, and those which were previously the most attractive being in like manner repelled; or, on the other hand, there may be a peculiar intensification of some one class of feelings or impulses, which thus acquire a settled domination over the whole character, and cause every idea with which they connect themselves to be presented to the mind under an erroneous aspect. The first of these forms, now generally termed *Moral Insanity*, *may* and frequently *does* exist without any disorder of the Intellectual powers, or any delusion whatever; it being (as we shall presently see) a result of the generality of the affection of the Emotional tendencies, that no one of them maintains any constant hold upon the

mind, one excitement being (as it were) driven-out by another. Such patients are among those whose treatment requires the nicest care, but who may be most benefited by judicious influences. Nothing else is requisite, than that they should exercise an adequate amount of self-control: but the best-directed moral treatment cannot enforce this, if the patient do not himself (or herself*) co-operate. Much may be effected, however, as in the education of children, by presenting adequate *motives* to self-control, and the more frequently this is exerted, the more easy does the exertion become.

708. The more limited and settled disorder of any one portion of the emotional nature, however, gives an entirely different aspect to the character, and produces an altogether dissimilar effect upon the conduct. It is the essential feature of this state, that some one particular tendency acquires a dominance over the rest; and this may happen, it would seem, either from an extraordinary exaggeration of the tendency, whereby it comes to overmaster even a strongly-exercised Volitional control; or, on the other hand, from a primary weakening of the Volitional control, which leaves the predominant bias of the individual free to exercise itself. Again, the exaggerated tendency may operate (like an ordinary Emotion), either in directly prompting to some kind of action which is the expression of it, or in modifying the course of thought, by habitually presenting erroneous notions upon the subjects to which the disordered feeling relates, as the basis of Intellectual operations.—The first of these forms of *Monomania* is that which is known as *impulsive* Insanity, and the recognition of its existence is of peculiar importance in a juridical point of view. For whilst the Law of England only recognizes as *irresponsible*, on the ground of Insanity, those who are incapable of distinguishing right from wrong, or of recognizing the consequences of their acts, it is unquestionable that many criminal actions are committed under the irresistible dominance of some insane impulse, the individual being at the time perfectly aware of their evil nature and of his amenableness to punishment.† Such an

* This form of Insanity is particularly common among females of naturally 'quick temper,' who, by not placing an habitual restraint upon themselves, gradually cease to retain any command over it.

† The following very characteristic example of the Homicidal form of impulsive Insanity, is given in the Report of the Morningside (Edinburgh) Lunatic Asylum for the year 1850.—The case was that of a female, who was not affected with any disorder of her intellectual powers, and who laboured under no delusions or hallucinations, but who was tormented by "a simple abstract desire to kill, or rather, for it took a specific form, to strangle. She made repeated attempts to effect her purpose, attacking all and sundry, even her own nieces and other relatives; indeed, it seemed to be a matter of indifference to her *whom* she strangled, so that she succeeded in killing *some one*. She recovered, under strict discipline, so much self control as to be permitted to work in the washing house and laundry; but she still continued to assert that she 'must do it,' that she was 'certain she would do it some day,' that she could not help it, that 'surely no one had ever suffered as she had done, —was not hers 'an awful case,' and, approaching any one, she would gently bring her hand near their throat, and say mildly and persuasively, 'I would just like to do it.' She frequently expressed a wish that all the men and women in the world had only one neck, that she might strangle it. Yet this female had kind and amiable dispositions, was beloved by her fellow-patients, so much so that one of them insisted on sleeping with her, although she herself declared that she was afraid she would not be able to resist the impulse to get up during the night and strangle her. She had been a very pious woman, exemplary in her conduct, very fond of attending prayer-meetings, and of visiting the sick, praying with them, and reading the Scriptures, or repeating to them the sermons she had

impulse may lead the subject of it to kill, to commit a rape, to steal, to burn, and so on, and this without the least intention of doing injury to another, and many instances have occurred, in which the individuals thus affected have voluntarily withdrawn themselves from the circumstances of whose exciting influence they were conscious, and have even begged to be put under restraint.—It is a remarkable fact, moreover, and one that strikingly confirms the view of the nature of Emotional states which has been here advocated, that the insane impulse appears to be not unfrequently the expression of a dominant *idea*, with which there is no such association of pleasurable feeling as makes the action prompted by it an object of *desire*, but which operates by taking full possession of the mind, and by forcing (so to speak) the body into the movements which express it. The individual thus affected regards himself as the victim of a *necessity* which he cannot resist, and may be perfectly conscious (as when the impulse proceeds from a strong desire) that what he is doing will be injurious to others or to himself. This state bears a close resemblance to that of the 'biologized' subject, who is peremptorily told, "You *must* do this," and does it accordingly (§ 672); and it is one that is particularly liable to be induced in persons who habitually exercise but little Volitional control over the direction of their thoughts, by the influence of suggestions from without, and especially by occurrences which fix themselves strongly upon their attention.*

heard. It was the second attack of insanity. During the former, she had attempted suicide. The disease was hereditary, and it may be believed that she was strongly predisposed to morbid impulses of this character, when it is stated that her sister and mother both committed suicide. There could be no doubt as to the sincerity of her morbid desires. She was brought to the Institution under very severe restraint, and the parties who brought her were under great alarm upon the restraint being removed. After its removal, she made repeated and very determined attacks upon the other patients, the attendants, and the officers of the Asylum, and was only brought to exercise sufficient self-control by a system of rigid discipline. This female was perfectly aware that her impulses were wrong, and that if she had committed any act of violence under their influence, she would have been exposed to punishment. She deplored, in piteous terms, the horrible propensity under which she laboured."—In the Report of the same Institution for 1853, it is mentioned that this female had been re-admitted, after nearly succeeding in strangling her sister's child under the prompting of her homicidal impulse. "She displays no delusion or perversion of ideas, but is urged-on by an abstract and uncontrollable impulse to do what she knows to be wrong, and deeply deplores."

* To this condition are to be referred many of the insane actions which are commonly set down to the account of *Imitation*. This term would be best restricted to that state of mind, in which there is an *intention* to imitate; for what is called 'involuntary imitation' is merely the expression of the fact, that the consciousness of the performance of a certain act by one individual, gives rise to a tendency to its performance by the other. Thus the excitement of the act of yawning by the sight or the sound of it in another, is a simple phenomenon of *consensual* movement proceeding from an *exciting sensation*. And in like manner, the commission of suicide or homicide, after an occurrence of the same kind which has previously fixed itself strongly upon the attention, is an *ideo-motor* action, prompted by a *suggesting idea*. Thus, it is well known that after the suicide of Lord Castlereagh, a large number of persons destroyed themselves in a similar mode. Within a week after the "Pentonville Tragedy," in which a man cut the throats of his four children and then his own, there were two similar occurrences elsewhere. After the trial of Henriette Cornier for child-murder, which excited a considerable amount of public discussion on the question of homicidal insanity, Esquirol was consulted by numerous mothers, who were haunted by a propensity to destroy their offspring.—The following is a remarkable example of the *sudden* domination of a morbid impulse, to which no tendency seems to have been previously experienced, and which appears to have been altogether devoid of any emotional

709. In most forms of Monomania, however, there is more or less of disorder in the *Ideational* process, leading to the formation of positive *delusions* or *hallucinations*, that is to say, of fixed beliefs or 'dominant ideas,' which are palpably inconsistent with reality. These delusions are not attributable to original perversions of the reasoning process, but *arise out of* the perverted Emotional state. This gives-rise, in the first place, to a mis-interpretation of actual occurrences in accordance with the prevalent state of the feelings (§ 623); but when the disorder has lasted some time, ideas which have had their origin in the Imagination alone, and which it has at first presented under a very transient aspect, are habitually dwelt-upon in consequence of the interest with which they are invested, and at last become realities to the consciousness of the individual, simply because he has not brought them to the test of actual experience.*

character. Dr. Oppenheim, of Hamburgh, having received for dissection the body of a man who had committed suicide by cutting his throat, but who had done this in such a manner that his death did not take place until after an interval of great suffering, jokingly remarked to his attendant,—"If you have any fancy to cut your throat, don't do it in such a bungling way as this; a little more to the left here, and you will cut the carotid artery." The individual to whom this dangerous advice was addressed, was a sober, steady man, with a family and a comfortable subsistence; he had never manifested the slightest tendency to suicide, and had no motive to commit it. Yet, strange to say, the sight of the corpse, and the observation made by Dr. O., suggested to his mind the idea of self destruction; and this took such firm hold of him that he carried it into execution, fortunately, however, without duly profiting by the anatomical instructions he had received; for he did not cut the carotid, and recovered.

* The Author was led, several years since, to the formation of the view above enunciated with regard to the Emotional source of most if not all the *delusions* of the Insane, by the careful observation of a case in which the gradual formation of such delusions could be traced, and in which the varying tenacity of their hold over the belief (which sometimes appeared disposed to get rid of them) corresponded exactly with varying degrees of intensity of the dominant emotion. Having been led, by his interest in this case, to make particular inquiries as to the point in question, among those whose experience of Insanity has been far more extensive than his own, he has obtained from them full confirmation of the view above expressed. Thus Dr. Skae remarks in the "Morningside Report" for 1853, that "nothing can be further from the truth than to believe that in every case of Insanity there must be some delusion, or some perturbation of the intellect. Of all the features of Insanity, *morbid impulses, emotions*, and *feelings*, and the *loss of control over them*, are the most essential and constant. Delusions, illusions, and hallucinations are, comparatively speaking, the accidental concomitants of the disease. The former, perhaps, invariably accompany the invasion of the disease; the latter are frequently only developed during its progress, and are sometimes never present at all." It is not a little interesting, in this connexion, as well as in the additional relation which it indicates between Insanity and the various phases of Delirium, Dreaming, &c., that the *particular delusion* seems often to be suggested by accidental circumstances, the mind being previously under the influence of some morbid tendency which gave the *general direction* to the thoughts. Thus we find it mentioned in the "Morningside Report," for 1850, that the Queen's public visit to Scotland seemed to give a special direction to the ideas of several individuals who became insane at that period, the attack of insanity being itself in some instances traceable to the excitement induced by that event. One of the patients, who was affected with puerperal mania, believed that, in consequence of her confinement having taken place on such a remarkable occasion, she must have given birth to a person of royal or divine dignity. During the religious excitement which prevailed at the time of the 'disruption' of the Scottish Church, an unusually large number of patients were admitted into the various asylums of Scotland, labouring under delusions connected with religion; the disorder having here also doubtless commenced in an exaggeration of this class of *feelings*, and the erroneous *beliefs* having been formed under their influence. Again, in the Report of the same Institution for 1851, it is stated that, as in former instances, "the current topics of the day gave colouring and form to the delusions of the disordered fancy. We have thus had no less than five individuals admitted during the year, who believe themselves the victims of

When the mind has once yielded itself up to the dominance of these erroneous ideas, they can seldom be dispelled by any process of reasoning; for it results from the very nature of the previous habits of thought, that the reasoning powers are weakened, and that the volitional control, through want of exercise, can no longer be exerted.* And, consequently, although a vigorous determination to get-rid of the ideas which are felt to be erroneous, and to keep-down the emotional tendency whose exaggeration is the essence of the disorder,—in other words, a strong effort of self-control,—may be effective in an early stage of this condition, yet, when the wrong habits of thought have become settled, little can usually be done by way of direct attack upon them; and the most efficacious treatment consists in the encouragement of the general habit of self-control, and in the withdrawal of the mind, so far as may be possible, from the morbid state of action, by presenting to it other sources of interesting occupation.†

710. A disordered state of the Emotional nature seems to be an essential character of that condition which is usually designated as *Hysteria*. There are certain forms of this disorder, which graduate insensibly into Moral Insanity or Monomania; but it more commonly manifests itself, in the first instance at least, in an exaggeration of ordinary emotional excitement and of its external manifestations, such as smiles and tears, laughter and crying, which are strangely intermingled, and are brought-on by the slightest disturbance of the feelings. That the deficiency lies rather in the power of controlling the *thoughts* and *feelings*, than in that of directing the actions of the *muscles*, appears from the fact that Hysterical patients can often be caused to restrain themselves, either by the presentation of some powerful motive (as the threat of severe discipline in the event of the return of the paroxysm), or through the more gradual cultivation of the power of Will in repressing the first access of emotional excitement, by the withdrawal of the mind from the contemplation of all that induces it. For in such individuals, the involuntary movements are but the expression of an unhealthy state of mind; in which, either from an injudicious system of education, or from habitual want of self-control on the part of the individual, the Emotions are allowed to exercise unchecked domination; and in which the Will is at last so weakened, that the subject of the disorder can scarcely be considered as a responsible being.—There are other Hysterical cases, again, in which there is less of mental disorder, but a greater physical excitability of the nervous system (§ 723), so that most violent paroxysms of a tetanic or epileptic character are induced by very slight stimuli; and any emotional excitement may act

Mesmeric agency,"—a sort of 'Mesmeric mania' having been prevalent in Edinburgh during that period, "three of the inmates talked much of California, and of the bags full of gold which they had obtained from the diggings, and one of them arrived at the persuasion that his body was transmuted into gold."—That Insanity commences in a disordered Emotional state, is a doctrine long since advocated by M. Guislain ("Traité des Phrénopathies," and "Leçons Orales sur les Maladies Mentales"), but he only recognises one form of this disorder, that of *painful* sensibility of mind.

* If an attempt be made to reason a patient out of a delusion, by demonstrating its complete inconsistency with the most obvious facts, the reply will be usually something to this effect,—"I have stronger evidence than anything which *you* can urge—the evidence of *my own* feelings."

† See an excellent little essay by the Rev. J. Barlow, on "Man's Power over himself to prevent or control Insanity."

as one among these stimuli, without, however, being at all excessive in its amount. Here, too, the Will may have a perfect control over the muscles, at all other times than when they are thrown into violent action by the reflex excitability of the Automatic centres; and the treatment of such cases must be in great degree directed to the removal of this excitability, which frequently depends upon some morbid condition of the uterus or ovaries. At the same time, there is no doubt that an habitually-perturbed state of the Emotions, and especially of those relating to sexual love (§ 723 *note*), has a most decided influence both in first inducing and in subsequently maintaining this automatic excitability; and that whilst mental tranquillity and self-regulation are almost essential to recovery, nothing promotes it so much as the supervention of a more favourable state of feeling, arising out of the prospective realization of desires repressed or of hopes deferred. Although Hysteria is so much more common in the female than in the male sex, that it has been often supposed to be peculiar to the former, and to be essentially connected with some disordered state of the generative function, yet there is no doubt of its occasional occurrence in the latter also; and its greater frequency in Woman may be fairly attributed to the greater predominance of the Emotional element in her mental constitution; as well as to the circumstance, that in all that relates to sexual love, she is frequently restrained by a sense of decorum from giving outward expression to feelings which she is secretly brooding-over, and whose injurious influence she is exaggerating by the attention she gives to them. Where the natural vent is not found for these emotions in a reciprocated attachment, the principle formerly laid down (§ 640) would indicate, that the mind should be led to seek-out for itself *other* objects of interest sufficiently attractive to solicit its attention, and that the pent-up excitement should be encouraged to discharge itself on these; and experience shows that such is a most important part of the cure for these states, provided that motives can be found of sufficient strength to influence the Will to exert its self-directing power.*

711. The disorder of the Ideational process which is induced by Emotional perversion, frequently leads to the formation of those erroneous notions of the nature of the external objects whereby the subject of it is environed, which are commonly termed *false perceptions*. It is not clear, however, how far the act of Perception (using this term in the sense to which it is properly restricted, § 603) is itself perverted in such cases; and it is certain that the source of the distortion frequently lies, chiefly or even solely, in the Emotional medium through which the perceptions are interpreted (§ 623). Thus, a Lunatic who is possessed with an exaggerated feeling of his own importance, may suppose himself to be a sovereign prince; and under the influence of this 'dominant idea,' looks upon the place of his confinement as his palace, believes his keepers to be his obsequious officers, and his fellow-patients to be his obedient subjects; the plainest fare is converted into a banquet of the choicest dainties, and the most homely dress into royal apparel. His condition, therefore, closely corresponds with that of a 'biologized' subject, whose mind may become 'possessed' for a time by similar ideas through the influence of

* For a sagacious analysis of this condition, and of the remedies for it, see a small treatise by Mr. R. B. Carter "On the Pathology and Treatment of Hysteria."

external suggestion (§ 672), and who is not undeceived by their discordance with objective realities, because the force with which the consciousness is impressed by the latter, is less than that with which it is acted-on by the former. Now and then, perhaps, the lunatic, like the biologized subject, is visited by a gleam of common-sense, which enables him to view certain objects in their true light, so that he becomes sensible of some inconsistency between his real and his imaginary condition; thus, a patient in a Scotch pauper-lunatic asylum, after dilating upon the imaginary splendours of his regal state, confessed that there was one thing which he could not quite comprehend, namely, that all his food tasted of oatmeal! —It is not only in Insanity, however, that we witness the influence of dominant ideas or feelings in producing a misinterpretation of Sensational states; for we have already noticed instances, in which the same influence was apparent in the ordinary working of the sane mind (§§ 600, 601). The following example of such an influence, affecting several individuals simultaneously in a similar manner, is mentioned by Dr. Hibbert in his well known Treatise on Apparitions. A whole ship's company was thrown into the utmost consternation, by the apparition of a cook who had died a few days before. He was distinctly seen walking a head of the ship, with a peculiar gait by which he was distinguished when alive, through having one of his legs shorter than the other. On steering the ship towards the object, it was found to be a piece of floating wreck. —Many similar cases might be referred-to, in which the imagination has worked-up into 'apparitions' some common-place objects, which it has invested with attributes derived from the previous mental state of the observer; and the belief in such an apparition as a reality, which usually exists in such cases, unless antagonized by an effort of the reason, constitutes a *delusion*. The origin of such *delusions* is thus essentially Cerebral; whilst that of pure *illusions* is probably Sensorial (§ 716). In many cases, however, there is probably a disordered action of *both* centres from the same cause, as is obviously the case in those forms of Delirium which have a *toxic* origin (§ 702).*

712. Without any Mental perversion indicative of either structural or functional disorder of the Cerebrum, there may exist a partial severance of its connection with the motor apparatus; so that there is a weakening of Volitional power over the muscles, whilst they still remain amenable to the stimulus of Emotion, which seems to proceed immediately from the Sensory Ganglia; and in such cases, as might be expected, the influence of sensory impressions in directly exciting muscular movements, is very strongly marked.† Of the precise alterations which give rise to these

* Two interesting Essays on 'Hallucinations,' by M. Michéa and Baillarger, will be found in "Mem. de l'Acad. Roy. de Medecine," tom. xii.

† Of this curious state, the following example was communicated to the Author, some years since, by his friend Dr. Noble.—"Mr. R. æt. 41, of a sanguine nervous temperament, a married man, and father of several children, the youngest being but two months old, exhibited the following symptoms, first experienced in a slight degree about five years ago, and since then having become much aggravated, the climax having apparently been attained about two years ago. There was partial paralysis of voluntary motion upon the left side, exhibiting under ordinary circumstances the customary phenomena; but with this peculiarity,—that although Volition was comparatively powerless, any incident excitor impression of an unusual character, by exciting, as it were, Consensual action, would give effect to the voluntary intention; thus, when the affected arm was raised by another to a certain height, the patient was unable by mere volition to

peculiar conditions, nothing whatever is known;—Nearly allied to this state is that which gives rise to the 'jactitating convulsion,' interfering with volitional movement, which is known as *Chorea*. On the physiological views here advocated, this disease must be regarded as consisting essentially in the diminution of the power of the Will (exerted through the Cerebrum) over the muscular apparatus, concurrently with an augmented and perverted activity of the Sensori-motor centres. That its special seat is at the summit of the Cranio-Spinal axis, where it comes into connection with the Cerebrum, would appear from several considerations, particularly from the interruption of voluntary power, the aggravation of the movements by emotion, and their cessation during sleep; the two latter facts being inconsistent with the idea that the proper Spinal centres are essentially involved, although they are frequently affected coincidently or subsequently. The Choreic convulsion is occasionally hemiplegic; and it sometimes gives place to paralysis, which is seldom complete, however, and may usually be cured by appropriate treatment. This disorder appears generally traceable to a state of imperfect nutrition, dependent upon a depraved and perhaps a poisoned state of the blood, rather than to any organic lesion.* Not unfrequently, the defect of nutrition seems to act as the 'predisposing cause' of the disease, the attack being immediately traceable to mental emotion.†—But there are other states of less intensity, in which Emotional excitement has a morbid power of inducing muscular movements; and this not through any deficiency of due control over the feelings, but often concurrently with a want of power to bring the Will to bear upon the muscles. Thus, there are individuals not at all remarkable for their emotional excitability, who cannot avoid making the most extraordinary grimaces whenever anything happens which in the least disturbs their usual equanimity, notwithstanding that they may put-forth all the efforts in their power to prevent these.‡ The

elevate it still more; but if the hand were smartly struck or blown-upon either by himself or by another, movement of a rapid character would at once ensue, and that too in conformity with the volitional effort. Upon inquiry, moreover, it appeared that any unwonted impression upon the internal as well as the external senses was capable of leading to a realization of the effort vainly attempted by the mere Will; hence by accomplishing the commencement of a *run* or *trot* by aid of some undue impression, he could go on; he stated, on the case being proposed, that if, in utter paralysis of voluntary power over the muscles, a hundred pound note were suddenly placed before his vision, and he were told that on seizing it the same should be his, he should at once be equal to the requisite effort. —When in health, Mr. R stated that he had excellent controlling power over the Emotions, but that now the pleasure and the pain attendant upon their excitation were exalted, and the consensual phenomena quite irresistible, and on further inquiry it appeared that, in the matter of laughing and crying, he exhibited very much of the hysterical condition. In early life, Mr. R. had been what is called a free liver; both in regard to women, and to alcoholic stimulants."

* See Dr Todd's Lumleian Lectures 'On the Pathology and Treatment of Convulsive Diseases' in the "Medical Gazette," April 20 and 27, 1849.

† A remarkable number of cases of Chorea were admitted into the Bristol Infirmary within a few weeks after the memorable Riots of 1833.

‡ The Author has at present a case under his observation, in which not merely the face, but the body and limbs, are thrown into the most extraordinary contortions, upon any agitation of the feelings, however trifling. This gentleman, a man of education and intelligence, of extreme benevolence of character, and a mind habitually well-regulated, can scarcely walk the streets without being liable to the induction of paroxysms of this kind, by causes that could scarcely have been supposed capable of thus operating. For

general muscular agitation of the confirmed Stammerer (§ 821) is another case in point; here we have a deficiency in the power of the Will over the Muscles, at first displayed only in regard to those of Voice; but when feelings of discomfort have been aroused by the failure of attempts to articulate, this want of voluntary control extends itself to the muscular system in general, which is thrown into a sort of paroxysmal effort, that usually subsides only with the explosion of the desiderated sound.

713. The *Sensory Ganglia*, collectively constituting the *Sensorium*, may be regarded as the most essential part of the Encephalon; since we find them fully developed in animals which scarcely possess a rudiment of a Cerebrum, and presenting the same relative condition to the latter in the early embryo of Man. They directly receive the nerves proceeding from the organs of Special Sense, each pair of which has its own distinct ganglionic centre; and they receive also, through the (so-called) Crura Cerebri, the nerves of 'common sensation,' whose ganglionic centre appears to lie in the Thalami Optici. They give-off a large number of motor fibres, which, descending through the Crura Cerebri, are distributed, with the fibres proceeding from the Spinal ganglia, through the various motor trunks, to the muscular system generally. On the other hand, by one set of the radiating fibres of the Cerebral substance, they transmit sensorial impressions upwards to the vesicular surface of the Hemispheres; whilst conversely, by its descending fibres, they receive the impressions transmitted downwards from the Cerebral ganglia, and they thus constitute the medium by which alone the Cerebrum communicates with the Organs of Sense on the one hand, and with the Muscular apparatus on the other.—The Sensory Ganglia must be regarded as collectively forming the *Sensorium*, through whose instrumentality the Mind is rendered conscious of impressions made on the Organs of Sense; and reasons have been advanced for the belief, that it also serves as the instrument whereby the Consciousness is affected by Cerebral changes, which, in so far as they take place independently of the Will, are the cause and not the consequence of Mental activity. This impression on the consciousness, when made by an external agency operating through the sensory nerves, is that which is known as *Sensation*: but, when produced by Cerebral changes, it constitutes *Ideation*. With these states of consciousness are directly associated the simple *feelings* of pleasure and pain, together with other modes of sensibility, which are designated as Æsthetic, Moral, Emotional, &c.; together with that direct perception of *reality*, whether in the external universe (objective), or in the world of ideas (subjective), which is termed *Intuition*. The seat of affections of the consciousness which are so directly linked-on to Sensations as with difficulty to be separated from them, can scarcely be other than Sensorial.—The 'reflex action' of the Sensory Ganglia, which proceeds from their own independent activity, is manifested in all those *automatic* movements, which are

example, he was one day seized by one of these attacks, in consequence of seeing a man miss his footing (as he thought) in descending from the top of an omnibus, and the pleasurable excitement of meeting a friend usually induces the same result. The tendency varies very considerably in its degree, according to the general condition of his health.

excited through sensations, and which may hence be designated as *consensual* or *sensori-motor*. These actions are but little noticed, in Man, in the active state of his Cerebrum; for the automatic movements on which the maintenance of his organic functions is immediately dependent, are provided-for by the Spinal centres; and the purposes which are answered in the lower animals by the higher order of Instinctive actions, are worked-out in him by the Intelligence. There is, however, a large group of *secondarily-automatic* movements, which though originally determined by the Will, are brought by habit so far under the direct influence of sensations, that they continue, whilst prompted and guided by the latter, after the Will has ceased to act.—The operation of the Sensory Ganglia in Man is usually subservient to that of the Cerebrum; for the influence of Sensational changes, being propagated upwards to that organ, excites further changes in it; these, reflected downwards to the Sensori-motor centres, become the sources of ideational or of emotional movements; and the determining power of the Will, in producing volitional movements, is exercised through the same channel. It is a remarkable indication of the participation of the Sensorial centres even in volitional movements, that these cannot be executed save with the concurrence of *guiding sensations*.

714. The extent to which the Sensory Ganglia may act as independent centres of action, is best seen in cases in which the functions of the Cerebrum are entirely in abeyance. This may happen through congenital defect, as in some cases of complete Idiocy, especially among the Cretins of the 'first degree,' who spend their whole time in basking in the sun or sitting by the fire (experiencing merely sensorial pleasure), and who show no higher traces of intelligence, than is evinced by their going, when excited by hunger, to the places where they have been accustomed to receive food. It may occur, too, as a consequence of disease or injury. Of this we have an example in a case mentioned by Dr. Rush, of a man who was so violently affected by some losses in trade, that he was deprived almost instantly of his mental faculties; he did not take the slightest notice of anything, not even expressing a desire for food, but merely receiving it when it was put into his mouth; a servant dressed him in the morning, and conducted him to a seat in his parlour, where he remained the whole day, with his body bent forwards, and his eyes fixed on the floor; in this state he continued for five years, and then recovered completely and rather suddenly. The well-known case of a sailor who suffered for more than a year from depressed fracture of the skull, and was at last restored to his normal condition by the elevation of the depressed bone (which was effected by Mr. Cline), affords another illustration of the same suspension of cerebral activity, without the loss of sensorial power; this man passed the period between the accident and the operation in a condition very similar to that of the subject of the preceding case, and after his recovery, the whole intervening space was a perfect blank to his recollection. The most remarkable example of this condition, however, yet put on record, is a case which occurred a few years ago under the observation of Mr. Dunn,* of whose excellent account an abridgment is here given, for the sake of illustrating the nature of a purely *sensorial* and *instinctive*, as distin-

* "Lancet," Nov 15 and 29, 1845.

guished from an *intelligent* existence, and the gradual nature of the transition from the one to the other.* A very similar condition presents

* The subject of this case was a young woman of robust constitution and good health, who accidentally fell into a river and was nearly drowned. She remained insensible for six hours after the immersion, but recovered so far as to be able to give some account of the accident and of her subsequent feelings, though she continued far from well. Ten days subsequently, however, she was seized with a fit of complete stupor, which lasted for four hours; at the end of which time she opened her eyes, but did not seem to recognize any of her friends around her; and she appeared to be utterly deprived of the senses of hearing, taste, and smell, as well as of the power of speech. Her mental faculties seemed to be entirely suspended; her only medium of communication with the external world being through the senses of sight and touch, neither of which appeared to arouse *ideas* in her mind, though respondent *movements* of various kinds were excited through them. Her vision at short distances was quick, and so great was the exaltation of the general sensibility upon the surface of the body, that the slightest touch would startle her; still, unless she was touched, or an object or a person was so placed that she could not help seeing the one or the other, she appeared to be quite lost to everything that was passing around her. She had no notion that she was at home, not the least knowledge of anything about her; she did not even know her own mother, who attended upon her with the most unwearied assiduity and kindness. Wherever she was placed, there she remained during the day. . . . . . Her appetite was good, but having neither taste nor smell, she ate alike indifferently whatever she was fed with, and took nauseous medicines as readily as delicious viands. All the automatic movements unconnected with sensation, of which the spinal cord is the instrument, seemed to go on without interference; as did also those dependent upon the sensations of sight and touch; whilst the functions of the other ganglia, together with those of the cerebral hemispheres, appeared to be in complete abeyance. The analysis of the facts stated regarding her ingestion of food seems to make this clear. She swallowed food when it was put into her mouth; this was a purely automatic action, the reception by the lips being probably excited by sensation, whilst the act of deglutition, when the food is carried within reach of the pharyngeal muscles, is excited without the necessary concurrence of sensation. She made no spontaneous effort, however, to feed herself with the spoon; showing that she had not even that simple idea of helping herself, which infants so early acquire. But after her mother had conveyed the spoon a few times to her mouth, and had thus caused the muscular action to become associated with the sensorial stimulus, the patient continued the operation. It appears, however, to have been necessary to repeat this lesson on every occasion, showing the complete absence of memory for any idea, even one so simple and so immediately connected with the supply of the bodily wants. The difference between an *instinct* and a *desire* or *propensity*, heretofore dwelt on (§§ 561, 619), is here most strikingly manifested. This patient had an instinctive tendency to ingest food, as is shown by her performance of the actions already alluded to; but these actions required the stimulus of the present sensation, and do not seem to have been connected with any notion of the character of the object *as food;* at any rate, there was no manifestation of the existence of any such notion or idea, for she displayed no *desire for food* or drink in the absence of the objects, even when she must have been conscious of the uneasy sensations of hunger and thirst. The very limited nature of her faculties, and the *automatic* life she was leading, appear further evident from the following particulars. One of her first acts on recovering from the fit, had been to busy herself in picking the bed clothes; and as soon as she was able to sit up and be dressed, she continued the habit by incessantly picking some portion of her dress. She seemed to want an occupation for her fingers, and accordingly part of an old straw bonnet was given to her, which she pulled into pieces of great minuteness; she was afterwards bountifully supplied with roses; she picked-off the leaves, and then tore them into the smallest particles imaginable. A few days subsequently, she began forming upon the table, out of these minute particles, rude figures of roses and other common garden flowers; she had never received any instructions in drawing. —Roses not being so plentiful in London, waste paper and a pair of scissors were put into her hands; and for some days she found an occupation in cutting the paper into shreds; after a time these cuttings assumed rude figures and shapes, and more particularly the shapes used in patchwork. At length she was supplied with proper materials for patchwork, and after some initiatory instruction, she took to her needle and to this employment in good earnest. She now laboured incessantly at patchwork from morning till night, and on Sundays and week days, for she knew no difference of days; nor could she be made to comprehend the difference. She

itself, as the result of the complete exhaustion of Cerebral power, in those extreme forms of Dementia, or rather Amentia, which are frequently consequent upon repeated attacks of Mania, or a long succession of

had no remembrance from day to day of what she had been doing on the previous day, and so every morning commenced *de novo*. Whatever she began, that she continued to work-at while daylight lasted; manifesting no uneasiness for anything to eat or drink, taking not the slightest heed of anything which was going-on around her, but intent only on her patchwork. She gradually began, like a child, to register ideas and acquire experience. This was first shown in connexion with her manual occupation. From patchwork, after having exhausted all the materials within her reach, she was led to the higher art of worsted-work, by which her attention was soon engrossed as constantly as it had before been by her humbler employment. She was delighted with the colours and the flowers upon the patterns that were brought to her, and seemed to derive special enjoyment from the harmony of colours; nor did she conceal her want of respect towards any specimen of work that was placed before her, but immediately threw it aside if the arrangement displeased her. She still had no recollection from day to day of what she had done, and every morning began something new, unless her unfinished work was placed before her; and after imitating the patterns of others, she began devising some of her own. The first *ideas* derived from her former experience, that seemed to be awakened within her, were connected with two subjects which had naturally made a strong impression upon her; namely, her fall into the river, and a love-affair. It will be obvious that her pleasure in the symmetrical arrangement of patterns, the harmony of colours, &c., was at first simply *sensorial*; but she gradually took an interest in looking at pictures or prints, more especially of flowers, trees, and animals. When, however, she was shown a landscape in which there was a river, or the view of a troubled sea, she became intensely excited and violently agitated, and one of her fits of spasmodic rigidity and insensibility immediately followed. If the picture were removed before the paroxysm had subsided, she manifested no recollection of what had taken place; but so great was the feeling of dread or fright associated with water, that the mere sight of it in motion, its mere running from one vessel to another, made her shudder and tremble; and in the act of washing her hands they were merely placed in water. From this it may be inferred that simple *ideas* were now being formed; for whilst the actual sight or contact of moving water excited them by the direct sensorial channel, the sight of a picture containing a river or water in movement could only do so by giving rise to the notion of water. From an early stage of her illness she had derived evident pleasure from the proximity of a young man, to whom she had been attached; he was evidently an object of interest when nothing else would rouse her; and nothing seemed to give her so much pleasure as his presence. He came regularly every evening to see her, and she as regularly looked for his coming. At a time when she did not remember from one hour to another what she was doing, she would look anxiously for the opening of the door about the time he was accustomed to pay her a visit; and if he came not, she was fidgetty and fretful throughout the evening. When by her removal into the country she lost sight of him for some time, she became unhappy and irritable, manifested no pleasure in anything, and suffered very frequently from fits of spasmodic rigidity and insensibility. When, on the other hand, he remained constantly near her, she improved in bodily health, early associations were gradually awakened, and her intellectual powers and memory of words progressively returned. We here see very clearly the composite nature of the emotion of affection. At first, there was simple pleasure in the presence of her lover, excited by the gratification which the impress of former associations had connected with the *sensation*. Afterwards, however, it was evident that the pleasure became connected with the *idea*; she *thought* of him when absent, expected his return (even showing a power of measuring time, when she had no memory for anything else), and manifested discomfort if he did not make his appearance. Here we see the true *emotion*, namely, the association of pleasure with the *idea*; and the manner in which the *desire* would spring out of it. The desire in her then condition, would be inoperative in causing voluntary movement for its gratification; simply because there was no intellect for it to act upon. Her mental powers, however, were gradually returning. She took greater heed of the objects by which she was surrounded; and on one occasion, seeing her mother in a state of excessive agitation and grief, she became excited herself, and in the emotional excitement of the moment suddenly ejaculated, with some hesitation, "What's the matter?" From this time she began to articulate a few words; but she neither called persons nor things by their right names. The pronoun "this" was her favourite word;

Epileptic seizures. And it is also worth notice, that the "picking at the bed-clothes," which is so frequently seen towards the close of life, is a purely consensual movement, the performance of which is an indication of the torpor that has supervened upon the functional activity of the Cerebrum, and is, therefore, a most unfavourable symptom.

715. *Abnormal Modes of Sensori-Motor Activity.*—It is the *Sensorium* that is primarily, and (it may be) solely affected, in the state of *Coma;* which only differs from ordinary Sleep in the completeness of the suspension of the functional activity of the Sensory Ganglia. This suspension not merely prevents impressions transmitted from the organs of sense, from affecting the consciousness as Sensations; but it also interposes the same obstacle to that mental recognition of Cerebral changes, which, when the Sensorium is closed to the outer world, constitutes the state of Dreaming; and thus the comatose subject is not merely insensible to external impressions, but is cut-off from all perception of self-existence. There seems reason to believe, that, in the simpler forms of coma, such as we frequently meet-with in Hysterical subjects, there is no perversion of the functions of the Cerebrum; for we observe that, if the insensibility suddenly supervene in the midst of a sentence which is being uttered by the patient (a circumstance of no uncommon occurrence), the series of words is taken-up and completed the moment that the coma

and it was applied alike to every individual object, animate and inanimate. The first objects which she called by their right names were wild flowers, for which she had shown quite a passion when a child; and it is remarkable, that her interest in these and her recollection of their names should have manifested itself at a time when she exhibited not the least recollection of the "old familiar friends and places" of her childhood. As her intellect gradually expanded, and her *ideas* became more numerous and definite, they manifested themselves chiefly in the form of *emotions*, that is, the chief indications of them were through the signs of emotional excitement. These last were frequently exhibited, in the attacks of insensibility and spasmodic rigidity, which came-on at the slightest alarm. It is worth remarking that these attacks, throughout this remarkable period, were apt to recur three or four times a day, when her eyes had been long directed intently upon her work; which affords another proof how closely the emotional cause of them must have been akin to the influence of sensory impressions, the effects of the two being precisely the same.—The mode of recovery of this patient was quite as remarkable as anything in her history. Her health and bodily strength seemed completely re-established, her vocabulary was being extended, and her mental capacity was improving; when she became aware that her lover was paying attention to another woman. This idea immediately and very naturally excited the emotion of jealousy, which, if we analyse it, will appear to be nothing else than a painful *feeling* connected with the *idea* of the faithlessness of the object beloved. On one occasion this feeling was so strongly excited, that she fell down in a fit of insensibility, which resembled her first attack in duration and severity. This, however, proved sanatory. When the insensibility passed-off, she was no longer spell-bound. The veil of oblivion was withdrawn; and, as if awakening from a sleep of twelve months' duration, she found herself surrounded by her grandfather, grandmother, and their familiar friends and acquaintances, in the old house at Shoreham. She awoke in the possession of her natural faculties and former knowledge; but without the slightest remembrance of anything which had taken place in the interval, from the invasion of the first fit, up to the present time. She spoke, but she heard not; she was still deaf; but as she could read and write as formerly, she was no longer cut-off from communication with others. From this time she rapidly improved, but for some time continued deaf. She soon perfectly understood by the motion of the lips what her mother said; they conversed with facility and quickness together, but she did not understand the language of the lips of a stranger. She was completely unaware of the change in her lover's affections, which had taken place in her state of 'second consciousness,' and a painful explanation was necessary. This, however, she bore very well, and has since recovered her previous bodily and mental health.

passes-off, the patient being unconscious of the interruption; showing that there is none of that *confusion* of the Intellect, which marks Cerebral disorder. In a large proportion of cases, however, it is obvious, from the order in which the symptoms manifest themselves, that the Cerebrum is affected, as well as the Sensorial centres; of this the best evidence is afforded by the phenomena of alcoholic Intoxication, and the agency of narcotic poisons; and where Coma results from pressure within the cranium, this must act alike upon the Cerebrum and the Sensorium. Of the causes which induce the state of Coma, there are many which, when operating in smaller amount, or in less intensity, produce delirium. This is particularly the case with the whole group of truly narcotic poisons; and is true not merely of those which are introduced as such from external sources, but also with regard to those which are generated within the body. We have another illustration of it in the Coma of mere exhaustion, which is frequently preceded by delirium that is clearly attributable to nothing else than a deficient supply of blood. Still, we must not regard Coma as always indicating a more advanced state of morbid change, than that which occasions Delirium; for it stands to some forms of delirium, in the same light in which ordinary sleep stands to the waking state, being the repose which is required for reparation after a state of excessive mental activity. In fact, the profound sleep which succeeds a protracted period of severe bodily or mental exertion, is often almost comatose, as regards the degree in which the subject of it is insensible to external stimuli. The same may be stated with great probability of the coma which is consequent upon 'concussion' of the brain; for this may be regarded as a period of slow regeneration, during which the effects of the injury are being repaired by the nutritive processes; and any attempt to arouse the patient prematurely is far more likely to be injurious than beneficial, tending especially to increase the violence of the subsequent reaction. This state, in fact, is essentially one of *Syncope*, the suspension or reduction of the functional power of the Encephalic centres being mainly due to deficiency in the supply of blood which they receive, through the depression produced by the 'shock' in the action of the Heart (§ 238).

716. A state of disordered activity of the Sensorial centres appears to be the essential cause of the production of those *illusions* (most commonly *visual*, but not unfrequently belonging to some other sense), the origin of which is entirely independent of any ideational or emotional state, and in the reality of which the mind has no predisposition to believe (§ 711). The disordered action of the Sensational apparatus seems to be of the same kind with that which produces 'subjective sensations' (§ 597), extending only to the affection of the *Perceptional* consciousness; for it is, in fact, nothing else than the recognition of the apparent externality of the objects which thus affect the consciousness,—generally arising from their resemblance to well-known forms, voices, articulate sounds, &c.,—that distinguishes 'phantasms' or 'airy voices' from the subjective sensations on which they depend. These may deceive the mind, from their close resemblance to realities; thus Dr. Abercrombie mentions a case of a gentleman who had all his life been affected by the appearance of spectral figures, which so closely resembled the impressions produced by the real objects, that, on meeting a friend in the street, he could not satisfy himself whether

he saw the real individual or the spectral figure, save by touching his body, or by hearing the sound of his footsteps. But in most instances in which they have not been suggested by antecedent mental states, their appearance takes place under such circumstances, that even though they may produce reflex muscular actions (§ 599), the Intelligence is readily enabled to discriminate the false from the true. This was the case, for example, with Nicolai; who, when suffering from intermittent fever, saw coloured pictures of landscapes, trees, and rocks, resembling framed paintings, but of half the natural size; so long as he kept his eyes closed, they underwent constant changes, some figures disappeared while new ones showed themselves; but as soon as he opened his eyes, the whole vanished. In the case previously adverted to, the subject of these illusions could call-up spectral figures at his will, by directing his attention steadily to some conception of his own mind, which might either consist of a figure or a scene that he had seen, or might be a composition of his own imagination; but although possessing the faculty of producing the illusion, he had no power of banishing it; so that when he had called-up any particular figure or scene, he could not say how long it might continue to haunt him. This influence of the attention was noticed by Sir Isaac Newton in his investigation of ocular spectra; for he found that he could recal the spectrum of the sun after it had vanished, by going into the dark, and directing his mind intensely "as when a man looks earnestly to see a thing which is difficult to be seen." By repeating these experiments frequently, such an effect was produced upon his Sensorium, that for some months, he says, "the spectrum of the sun began to return, as often as I began to meditate on the phenomena, even though I lay in bed at midnight with my curtains drawn."* The essentially-automatic character of these false perceptions, however, is evident from the influence of *toxic* agents, such as opium, hachisch, or alcohol, fever-poison, &c., in producing them. That the mind of the individual thus affected should believe in them as realities, simply results from the circumstance, that, concurrently with the disorder of the Sensorium, the Cerebrum is also affected, so that its Intelligence is not in a fit state to correct the erroneous suggestions of the Senses.

717. It is, as we have seen, in the Sensorial centres, that those lesions are most commonly found, which give rise to Hemiplegic *Paralysis*. There can be little doubt that this form of paralysis is usually attributable to some structural disorganization of the nervous substance, produced by hæmorrhage, softening, &c. Still, this, like other forms of partial paralysis, may be *toxic*, depending rather upon the condition of the blood, than upon that of the nervous tissue. Of such toxic influence, we have a remarkable example in the peculiar local paralysis induced by the presence of Lead in the system; and there seems much reason to believe that some of the Hysterical forms of paralysis (as well as of convulsive disorders) are of toxic origin (§ 723). There are many instances, too, in which paralysis, like convulsion, seems to depend upon some injurious influence propagated from the nerves of some other part. Although it is

* A large number of interesting cases of Spectral Illusions will be found in Dr. Abercrombie's "Inquiry concerning the Intellectual Powers," under the head of 'Perception' and 'Spectral Illusions.' See also Sir B. Brodie's "Psychological Enquiries," and the Essay of M. Baillarger already referred-to.

in Hemiplegia that we have the most distinct evidence of disorder of the Encephalic centres, yet paralysis of any one part of the body may proceed from Encephalic lesion, and even some forms of Paraplegia seem traceable to disorders of the Cerebrum and Sensory Ganglia.* It is to a disturbance in the equilibrium of the Sensori Motor apparatus, consequent in some instances upon abnormal impressions received through the nerves of sense, and in others upon interruption to some of the ordinary channels of motor influence, that *Vertigo* is due;† which may either consist in abnormal subjective sensations only, or may exhibit disordered movements prompted by those sensations. This condition may be induced by certain lesions of the Sensori-Motor centres or of the Sensory Nerves (§§ 530–534); or it may depend upon the presence of certain toxic agents in the blood (as in Alcoholic intoxication), or it may proceed from a mere deficiency in the supply of blood to the Sensori-motor apparatus.

718. We seem entitled to consider the Sensory Ganglia as the primary seat of that combination of loss of sensibility with convulsive movements, which essentially constitutes *Epilepsy*. This is marked by the peculiar sensorial phenomena which usually precede the paroxysm; by the obliteration of consciousness, which is its prominent symptom; and by the peculiarity of the spasmodic contractions, which are *clonic* (or alternating with relaxation) instead of being *tonic* (or persistent), and which correspond with those that may be induced by artificial stimulation of this portion of the Encephalic centres (§ 535). The disordered action, however, manifestly extends itself to the Cerebrum; for a maniacal paroxysm frequently occurs in connection with the epileptic attacks; the attacks themselves are sometimes preceded, and very commonly followed, by considerable confusion of the intellect; the disease is seldom long persistent without impairing the memory and the control of the will over the mental operations; and in cases of long standing, the power of the Cerebrum appears to be almost entirely destroyed. There is very considerable diversity, on the other hand, in regard to the nature and intensity of the muscular convulsion; and there seems reason to think that when the morbid influence is determined downwards into the Motor apparatus, the Cerebrum escapes with a less serious impairment of its powers, since the destruction of the intellectual power occurs more surely where the fits are accompanied by much mental disturbance or stupor, than where the convulsive character predominates.—One of the most remarkable phenomena of Epilepsy is its tendency to periodic recurrence, with a more or less complete return to the normal state in the interval. This fact of itself seems to indicate that the disease cannot be fairly attributed to those obvious lesions of structure, which are sometimes coincident with it, and which, as Dr. Todd has justly remarked, are rather the signs of the altered nutrition brought-on by any cause which creates frequent disturbance of the actions of the brain, than the causes of that disturbance; for the influence of such lesions, if manifested at all (and it is remarkable

* For much valuable information on the different forms of Paralysis, see Dr. Gull's Gulstonian Lectures 'On the Nervous System' in the "Medical Times," 1849.

† For a summary of what is known as to the nature of this affection, with valuable suggestions for further enquiry, see Dr J. Russell Reynolds's "Essay on Vertigo," read to the North London Medical Society, 1854.

what an extent of disorganization *may* take place without any obvious indication), would be rather continuous than intermitting. It is quite certain, on the other hand, that death *may* occur from Epilepsy, without any appreciable lesion. It may be considered, also, as a well-established fact, that the epileptic paroxysm may be induced either by an insufficient supply, or by depravation of blood; of this we have examples in the epileptiform convulsions brought-on by excessive hæmorrhage in parturient women, in the epileptiform paroxysm induced by asphyxia (especially by strangulation), and in poisoning by hydrocyanic acid, the phenomena of which, in the lower animals especially, so closely simulate those of the genuine disease, that they may be designated as an artificial epilepsy. These and many other facts in the etiology of the disease, very strongly point to a disordered condition of the blood as its primal source; this acting either by altering the nutrition of the Encephalic centres, or by perverting their action, or in both modes conjointly, as in the case of Insanity (§ 705). According to the theory advocated by Dr Todd, a continual mal-nutrition of certain parts of the Encephalon occasions a gradually-increasing disturbance of their polar state, and this, when it has attained a certain measure of intensity, manifests itself in the epileptic paroxysm, just as a Leyden jar, when charged with electricity to a certain state of tension, gets rid of the disturbance of equilibrium by the "disruptive discharge."* The fact must not be disregarded, however, that when a state of mal-nutrition of the Nervous System has been established by causes which affect the condition of the Blood, the epileptic paroxysm may be induced by some eccentric or peripheral irritation, such as worms in the intestinal canal, the pressure of teeth in the eruptive stage of development against the capsule or the gum, &c.; neither cause being sufficient when acting alone. Hence, although the paroxysms may be suspended, and the disease apparently cured, by the removal of the peripheral source of irritation (as by the expulsion of the worms or the complete eruption of the teeth), the liability to it still remains, as is shown by the renewal of the paroxysms whenever any fresh irritation may arise. It is very important therefore, not to rest satisfied with local treatment in such cases; but to have recourse to measures adapted to produce a general invigoration of the system.†

719. The *Spinal Axis* (including the *Medulla Oblongata*) forms a continuous series of ganglionic centres, which are connected by afferent and efferent nerve-trunks with the several segments of the body; but these centres are enveloped in white or fibrous strands, which not only connect the various segmental divisions with each other, but also, there seems good reason to believe, establish a continuous connection between the Nerve-roots and the Sensorial centres. The independent activity of the Spinal centres is seen in the various reflex movements which are performed after they have been cut-off from all connection with the Encephalon; and of these reflex movements, there are certain definite groups,

* See Dr. Todd's 'Lumleian Lectures' in the "Medical Gazette," May 18, 1849, and the "Brit. and For. Med.-Chir. Rev.," Jan., 1850, pp. 24-33.

† The Author does not think it necessary here to devote any space to the examination of Dr. M. Hall's pathological theory of Epilepsy, which makes it depend upon spasmodic compression of certain muscles of the neck, producing compression of the veins and congestion of the cerebrum, since he considers that the fallacies of this theory have been already sufficiently pointed out by Dr. Todd (loc. cit.)

which are subservient to the functions of Respiration, Deglutition, Defecation, &c. In so far as these are performed by the Spinal Cord alone, without the participation of the Sensorium, they do not involve any affection of the consciousness; and as the separation of the Spinal Cord from the Sensorium effectually prevents the impression which excites the reflex movement from exciting sensation at the same time, we know that sensation cannot be necessary to the movement; hence this class of actions is best distinguished as *excito-motor*, in contradistinction to the *sensori-motor* in which Sensation necessarily participates. Putting aside, however, those actions which are subservient to the Organic functions, and which are performed in the state of full integrity and activity of the nervous system, we find that the reflex power of the Spinal Cord is only distinctly manifested when that organ is detached from the Encephalon; for in its normal state it serves as little else than the channel through which impressions are transmitted upwards to the Sensorium, and thence to the Cerebrum, and through which motor impulses are propagated downwards from these centres to the muscles. For the actions of the Spinal Cord are placed in subordination to the control of the Cerebrum, in every particular as to which they can be, without detriment to the welfare of the system generally; so that we find excitor impressions, which are quite competent to evoke reflex actions if they are prevented from travelling beyond the Cord, losing their power to do so when they are discharged (so to speak) into the Sensorium; whilst even the movements of Respiration, Defecation, &c., which do not require the participation of the Cerebrum in their ordinary performance, can be to a certain extent controlled by the Will.

720. *Abnormal Actions of the Spinal Cord.*—The functional activity of the Spinal Cord is capable of being morbidly diminished or augmented. It may even be for a time almost completely suspended, as in *Syncope* (§ 715): but it would seem as if a supply of blood which is insufficient to support the activity of the Encephalic centres, might still sustain (to a certain extent) the functional power of the Spinal system; for we find the respiratory movements and the power of swallowing to be the last to cease when the Heart's action is failing, and the first to return when it is becoming more vigorous. A corresponding state may be induced in particular portions of the system, by *Concussion*, as is seen in severe shocks to the Spinal Cord, which are almost invariably followed for a time by the suspension of its functions. Again the power of the whole Spinal Cord may be diminished by various causes, such as enfeebled circulation, pressure, &c.; and then we have torpidity and imperfect nutrition of the whole *muscular* system (§ 358 *note*). If oppression exist in the Brain, the functions of the Medulla Oblongata will be especially affected; and if it be prolonged and sufficiently severe, *Asphyxia* will result from the interruption of the respiratory movements which it occasions (§ 326); this, in fact, being the mode in which death is immediately produced in Narcotic Poisoning and other analogous states (Chap. XIX.). In the Convulsive diseases to be presently noticed, the fatal result is usually consequent upon a state of Asphyxia produced by the spasmodic fixation of the respiratory muscles.

721. On the other hand, the excitability of the whole Cord, or of particular parts of it, may be morbidly increased; as is the case in the

various classes of *Convulsive* diseases in which the consciousness is *not* affected. Of the distinct forms or combinations of which this class of disorders is composed, *Tetanus* is one of the most interesting and instructive. This disease essentially consists in an undue excitability of the whole series of Spinal Ganglia; so that very slight impressions produce violent and extensive reflex actions, the disturbance of nervous polarity induced by the impression, radiating (as it were) through the whole Cord, and affecting nerve-fibres that proceed from each of its different segments; and when this state is fully established, convulsive actions may proceed from purely *centric* irritation, no excitor impression being required to originate them. Such a state may be induced by various causes, among the most prominent of which are, on the one hand, those which affect the nutrition of the Cord, and, on the other, those which call it into disordered action, by altering the relations which the blood bears to it as the exciting fluid of the nervous battery. That which is termed the idiopathic form of the disease seems traceable to mal-nutrition of the Cord, consequent upon impoverishment or depravation of the blood; that, on the other hand, which is produced by the introduction of Strychnia into the blood, is dependent upon the peculiar potency of this substance in determining a wrong action of the Spinal centres, for which it seems to have an elective affinity, in the same way that alcohol and opium have for the encephalic. With regard to the traumatic form of Tetanus, it is impossible to say with certainty whether the peculiar condition of the Spinal Cord be determined, as in the preceding case, by the introduction of a poison into the blood, through some morbid action taking place in the wound; or whether the disturbance of the usual equilibrium be consequent upon the propagation of a morbid influence directly from the injured nerve-trunk to the Spinal centres, without any participation of the circulating System in this extension of the mischief. Whichever be the true account of it, this much is certain, that when the Tetanic state of the Spinal Cord is once fully established, nothing is gained by removal of the injured part; and powerful sedative remedies alone possess any influence in restraining the paroxysms. The Cerebral apparatus is entirely unaffected in this disorder; but the nerves of deglutition are usually those first influenced by it; those of respiration, however, being soon affected, as also those of the trunk in general.

722. The condition termed *Hydrophobia* is nearly allied to that of traumatic Tetanus, differing chiefly in the mode in which the Cranio-spinal axis is affected. The irritable state of the nervous centres obviously results from the introduction of a poison into the blood; and here the early removal of the wounded part is very desirable as a means of prevention; although, when the poison has once begun to operate on the centres, it is of no use. The muscles of respiration and deglutition are, as in Tetanus, those spasmodically affected in the first instance; but there is this curious difference in the mode in which they are excited to action,—that, whilst in Tetanus the stimulus operates through the Spinal Cord (either centrally, or by being conveyed from the periphery), in Hydrophobia it is often transmitted from the ganglia of Special Sense, or even from the Cerebrum; so that the sight or sound of fluids, or even the idea of them, occasions—equally with their contact, or with that of a current of air—the most distressing convulsions.

723. Many forms of that protean malady, *Hysteria*, are attended with a similar irritability of the Nervous Centres; but there is this remarkable difference in the two cases, that the morbid phenomena of Hysteria, whilst they often simulate those of Chorea, Tetanus, Hydrophobia, Epilepsy, &c., are evidently dependent upon a state of the system of a much less abnormal character. The absence of any structural lesion, and even of any serious impairment of the nutrition, of the parts of the Nervous System which are the sources of the actions in question, is proved by the length of time during which the severest forms of them may exist without permanently-serious consequences, and by the suddenness with which the several forms of them give place one to another, or pass-off altogether. The strange combinations, moreover, which they occasionally present, remarkably distinguish them from the more settled forms of the diseases which they simulate.* The clinical history of Hysteria, then, would lead us to suppose that the convulsive action depends rather upon some state of the blood which alters its relation to the nervous tissue as its exciting fluid, than upon any such change in the nutritive supply which it affords, as would induce a more permanent disorder in the system. Taking all the phenomena, however, into account, there seems much reason to think that a general excitability of the nervous

* Thus, the Author has known an obstinate case of Hysteric disorder, in which at one period attacks of the most complete Opisthotonos coexisted with perfect Coma; at another period, the Coma recurred alone; then, again, there was Trismus, lasting for five consecutive days, without any other spasmodic action or loss of sensibility; this sometimes alternated with fits of Yawning, in which the jaw was held open for half an hour together; at another period, the convulsions had more of the Epileptic character, the face being distorted, and the limbs agitated, concurrently with a state of Coma, but without laryngismus; with this alternated fits of Laryngismus, without insensibility, and occurring during the expiratory movement; whilst during the whole of this succession, there was Paralysis of the extensor muscles of both lower extremities, with paroxysms of the most violent and prolonged Cramp in one of them. The mental phenomena of this case were almost equally strange; for a state of almost Maniacal excitement often came-on suddenly, and ceased no less abruptly; and every form of Double Consciousness, from simple sleep-waking to an alternation of two very similar states of mental existence, presented itself during one long period of the disorder. It is worth noting that in this case the exciting cause of the disorder lay in the disappointment of affections long cherished in secret; but the nutrition of the nervous system had been previously impaired by anxiety and excessive mental exertion. The first access of the disorder was kept-off by the influence of a very determined will; but when the malady had fully developed itself, it resisted every kind of treatment for four years. The catamenial discharge remained very scanty during the whole of that time, and was sometimes absent altogether; and the recurrence of the period was almost invariably marked by an aggravation of the spasmodic attacks, and frequently by pains resembling those of the first stage of labour. A slow and almost imperceptible improvement was taking place, when circumstances occurred which gave a new turn to the feelings; a fresh attachment was formed, which was happily reciprocated; and from that time the cure rapidly advanced, the convulsive and paraplegic affections being speedily recovered from, and nothing being left but dysmenorrhœa, which still continued to be occasionally accompanied by severe cramps, and sometimes by general convulsion, coma, &c. This was not altogether corrected, though improved, by marriage; and any emotional excitement of an unpleasant kind was sure to produce an additional aggravation. The state of the os uteri was then examined; and as it was found to be unduly contracted, cautious dilatation by sponge tents was practised. This had the best results; the dysmenorrhœa soon abated, pregnancy supervened, and after a miscarriage (which seemed traceable to emotional excitement, coinciding with the monthly nisus) a second pregnancy followed, which went-on to the full term; and no return of the spasmodic attacks has since occurred. It is worthy of note that in this case there was an hereditary predisposition to Gout, which seemed once to manifest itself in a peculiar affection of the tissues about the wrist-joint, of a character rather gouty than rheumatic.

system, such as is only an exaggeration of that which is characteristic of the female sex, is induced by some defect of Nutrition, comparatively permanent in its nature; whilst the particular forms of perverted action are determined either by some toxic agent in the blood, slight variations in which may give it a selective power for one part or another of the Nervous Centres, or by irritation of the peripheral nerves. Among the sources of imperfect nutrition, leading to undue excitability of the nervous system, and thus acting as a 'predisposing cause,' it seems probable that a gouty diathesis is one of the most frequent;* whilst among the 'exciting causes,' some irregular action of the sexual apparatus is among the most common, though it would not be correct to affirm, that disorder of the nutritive or secretory functions of the sexual system is essential to the production of the hysteric condition. The influence of Emotional states upon this condition (§ 710), is among the most remarkable features in the history of the disorder. There can be little doubt that habitual indulgence of the feelings, especially when these are of a painful kind, has a direct tendency to affect the nutrition of the nervous system; but when these feelings have special reference to sexual subjects, they will exert a powerful indirect influence, by fixing the mind on the genital system, and thereby modifying its condition (CHAP XV.)—Hence the treatment of Hysteria may be considered as requiring three classes of remedial means;—those, namely, which operate by improving the general state of nutrition of the Nervous System and by diminishing its excitability, these for the most part acting through the blood, and being directed to the increase of its nutritive components and to the elimination of any morbid matter which it may be suspected to contain; those, secondly, which operate by removing the exciting causes of the paroxysm, among which may be specially reckoned all such as promote the healthful performance of the menstrual function; and lastly, all those which act beneficially on the Mind, diverting or repressing painful emotions, or substituting pleasurable feelings in their place, and strengthening the general control of the Will.

724. The foregoing are the chief Convulsive diseases, in which the Spinal centres generally are involved, but there are many spasmodic affections of a more limited character, which are traceable to a morbid affection of some particular division of the Spinal Axis. Thus in the various forms of *Spasmodic Asthma*, the Medulla Oblongata would seem to be alone involved, the attacks of this disorder usually resulting from some internal irritation, either in the air-passages themselves, or in the digestive system, producing a reflex contraction of the muscular fibres of the bronchial tubes (§ 291). In the purely spasmodic stage of *Hooping Cough*, again, which frequently persists long after all inflammatory symptoms have subsided, we have another example of spasmodic action limited to the respiratory centres; and here we find distinct evidence that the morbid condition originates in the introduction of a poison into the blood. The same may be said of the *Croup-like Convulsion* or *Crowing Inspiration* of Infants, which is an obstruction to the passage of air through the Glottis, produced by a spasmodic contraction of the constrictors of the larynx; for although the spasmodic action may be immediately brought-on by various kinds of local irritation, such as

* See Dr. Laycock "On the Nervous Diseases of Women," pp. 161, et seq.

that occasioned by teething, by the presence of undigested food, or by intestinal disorder, yet there is no doubt that the excitable condition of the Nervous Centres, without which these influences would be inoperative, is dependent upon a defect of nutrition arising from unwholesome food, bad air, or some other cause affecting the system generally.*—Spasmodic closure of the Larynx may occur from other causes. When the *rima glottidis* is narrowed, by effusion of fluid into the substance of its walls, it is very liable to be completely closed by spasmodic action, to which the unduly-irritable condition of the mucous membrane will furnish many sources of excitement. Choking, again, does not result so much from the pressure of the food on the air-passages themselves, as from the spasmodic action of the larynx excited by this; and the dislodgment of the morsel by an act of vomiting, is the most effectual means of obtaining relief. —*Tenesmus* and *Strangury* are well-known forms of spasmodic muscular contraction, excited by local irritation acting through the Spinal centres. The abnormal action which leads to *Abortion* (CHAP. XVI.) is frequently excited in the same manner. —There is a form of *Incontinence of Urine*, which is very analogous to the morbid action just described; the sphincter has its due power; but the stimulus to the evacuation of the bladder is excessive in strength and degree, owing to the acridity of the urine or other causes. The part of the bladder upon which this appears chiefly to act, is the trigonum (which is well known to be more sensitive to the irritation of calculi, than the rest of the internal surface), and Sir C. Bell advises young persons who suffer during the night from this very disagreeable complaint, to lie upon the belly instead of the back, so that the contact of the urine with the trigonum may be delayed as long as possible.—Various remedial agents will probably be found to operate, by occasioning increased excitability in some particular segments of the Cord; so that the usual stimuli applied to the parts connected with these, will occasion increased muscular tension. This seems to be the case, for example, in regard to the influence of aloes on the rectum and uterus, cantharides on the neck of the bladder and adjoining parts, and secale cornutum on the uterus. The mode of influence of cantharides is illustrated by a curious case, related by Dr. M. Hall, of a young lady who lost the power of retention of urine, in consequence of a fatty tumour in the spinal canal, which gradually severed the Spinal Cord, and induced paraplegia. The power of retaining the urine was always restored *for a time* by a dose of tincture of Cantharides, which seems to have acted by augmenting the activity of that segment of the Cord with which the sphincter vesicæ is connected.

725. As Convulsive diseases are dependent upon excessive activity of the Spinal centres, so do various forms of *Paralysis* arise from disease of the Cord, affecting its proper ganglionic substance, or the connections of its nerve-roots with the Encephalon. If the latter only be impaired, we have an interruption of sensibility and voluntary motion, the reflex actions of the Spinal ganglia being still manifested; but if the former be involved, these reflex actions are suspended no less completely than are

* The influence of "change of air" is often as marked in this disease, as it is in the chronic stage of hooping-cough. That an impure atmosphere is of itself sufficient to induce fatal convulsive disorders in infants, has been proved on a former occasion (§ 338).

the sensori-volitional. There are many peculiar phenomena of Paralysis depending on Spinal lesion, however, which have not yet been explained on any physiological basis. Among these is the fact, to which Dr. Gull has prominently directed attention,* that in Paraplegia dependent upon lesion of the Cord, there is usually greater loss of motion than of sensation; whilst in Paraplegia dependent upon Encephalic disorder, or upon toxic agencies rather affecting the peripheral than the central portions of the nervous system (as seems to be generally the case, for example, in poisoning by lead), affections of the sensibility, sometimes beginning with hyperæsthesia, and then proceeding to more or less complete anæsthesia, usually constitute the prominent symptoms.

726. Our present knowledge of the Physiology and Pathology of the *Cerebellum* seems to justify the inference, that its special function consists in the co-ordination of voluntary movements; and the effects of lesions whose influence is limited to this organ, display themselves most constantly in the impairment of this power.—But there are pathological phenomena which seem to indicate, that a centre of sexual sensation has its place in or near the central lobe of the Cerebellum, and that, according to the degree of excitement or of depression of its functional activity, will be the strength or weakness of the sexual desire prompted by the sensation.

[In the foregoing view of the Functions of the Nervous System, the Author has endeavoured to exhibit this most difficult and in many parts obscure subject, under the aspect in which it now presents itself to his own mind, believing that he could thus best explain it to his readers. As his views have been arrived at by his own careful study of the subject, he has not thought it necessary to be continually referring to other Physiologists, with whose doctrines his own may have more or less of coincidence. He would here state, once for all, that of the older writers on this branch of Physiology, he regards Unzer and Prochaska (whose treatises have been lately re-published by the Sydenham Society) as having displayed the deepest insight into the truth; their doctrines requiring little more than the correction and extension which subsequent anatomical discoveries have afforded, to form part of the present fabric of the science. And he considers it as no unimportant confirmation of his own views, that although arrived at in complete ignorance of what Unzer had long previously put forth, they have proved to be in harmony, on all essential points, with those of so philosophic and penetrating a thinker.—Of modern Neurologists, the foremost rank is justly to be assigned to Sir C. Bell, for his discovery of the anatomical distinctness of the sensory and motor nerves, and for the inferences to which this discovery led. And the Author is quite of opinion that the re-discovery of the Reflex Function of the Spinal Cord by Dr. M. Hall (which he believes to have been entirely original on that gentleman's part) has constituted an era of no less importance; although Dr. H.'s limitation of the doctrine of reflex action to the Spinal centres, has subsequently tended, in the Author's opinion, rather to retard than to promote the progress of Neurology. In extending this view to the Sensory Ganglia, and in showing that they minister to a class of reflex actions peculiarly their own, the Author believes that he may claim to have made the first definite attempt to free it from this limitation; and for its further extension to the Cerebrum, Science is indebted to Dr. Laycock, to whose Essay on the Reflex Action of the Brain, the Author has already expressed his obligations. To these he would add the names of Sir H. Holland and Dr. Todd, as those of writers from whom he has derived many valuable suggestions, which have not, he trusts, been without fruit in his own mind. It is a circumstance not devoid of interest, that, during the present century, notwithstanding the large amount of anatomical and experimental inquiry which has been directed to the Nervous System both in France and in Germany, and the vast addition to our knowledge of *details* which has hence arisen, the great advances in the *general doctrines* of this department of the science should have been made by British Physiologists.]

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* "Gulstonian Lectures on the Nervous System," in "Medical Times," 1849, No. 495.

CHAPTER XII.

OF THE ORGANS OF THE SENSES, AND THEIR FUNCTIONS.

1.—*Of Sensibility in General.*

727. We have seen that the conscious Mind is affected by impressions made upon the corporeal organism,—or, in other words, that Sensation is produced, through the instrumentality of a certain part of the Encephalon termed the *Sensorium*, which is the general centre of the nerves both of 'special' and of 'common' sensibility; the former connect it with the special Organs of Sense, the latter with the body generally, to the several parts of which they are by no means uniformly distributed, some tissues being altogether destitute of them. Those parts of the body which are endowed with sensory fibres, and impressions on which, therefore, give rise to sensation, are ordinarily spoken-of as *sensible*, and different parts are said to be sensible in different degrees, according to the strength of the sensation produced by a corresponding impression on each. In accordance with the general fact of the dependence of all Nervous action on the continuance of the Circulation of the blood (see PRINC. OF GEN. PHYS.), it is found that the sensory nerves are distributed pretty much in the same proportion as the blood vessels; that is to say, in the non-vascular tissues,—such as the epidermis, hair, nails, cartilage, and bony substance of the teeth,—no nerves exist, and there is an entire absence of sensibility; and in those whose vascularity is trifling, as is the case with bones, tendons, ligaments, fibrous membranes, and other parts whose functions are simply mechanical, and even with serous and areolar membranes, there are few nerves, and the sensibility is dull. Many of these textures are acutely sensible, however, under certain circumstances; thus, although tendons and ligaments may be wounded, burned, &c., without giving rise to much consciousness of the injury, they cannot be stretched without the production of considerable pain; and the fibrous, serous, and areolar tissues, when their vascularity is increased by inflammation, also become extremely susceptible of painful impressions. All very vascular parts, however, do not possess acute sensibility; the muscles, for instance, are furnished with a large supply of blood, to enable them to perform their peculiar function; but they are not sensible in by any means the same proportion. Even the substance of the brain, and of the nerves of special sensation, appears to be destitute of this endowment; and the same may be said of the mucous membranes lining the interior of the several viscera, which, in the ordinary condition, are much less sensible than the membranes that cover those viscera, although so plentifully supplied with blood for their special purposes. The most sensible of all parts of the body, is the Skin, in which the sensory nerves spread themselves out into a minute network; and even of this tissue, the sensibility differs greatly in different parts (§ 733). The organs of *Special* Sensation become, by the peculiar

character of the nerves with which they are supplied, the recipients of impressions of a particular kind: thus, the Eye is sensible to light, the Ear to sound, &c., and whatever amount of *ordinary* sensibility they possess, is dependent upon other sensory nerves. The eye, for example, contrary to the usual notions, is a very insensible part of the body, unless affected with inflammation; for though the mucous membrane which covers its surface, and which is prolonged from the skin is acutely sensible to tactile impressions, the interior is by no means so, as is well known to those who have operated much on this organ. And the common sensory nerves, which supply certain parts of the body, are adapted to receive and convey to the mind impressions of particular kinds, with much greater readiness than they communicate those of a different description; thus the sensibility to tickling is much greater on some parts of the surface than on others; and this kind of excitement, applied to the genitals or to the nipple, produces sensations of a most peculiar order.

728. An active Capillary Circulation being essential to the sensibility of every part supplied with nerves, any cause which retards this deadens the sensibility, as is well seen with regard to Cold; and, on the other hand, an increase in its energy produces a corresponding increase in the sensibility, as is peculiarly evident in the 'active congestion' which usually precedes and accompanies Inflammation. A diminution or increase of sensibility to external impressions may arise, however, not only from an abnormal state of the circulation in the organ or part itself, but from the similar conditions affecting that part of the Sensorium in which the impressions are received. Thus in those various conditions of the Encephalon, in which either a stagnation of the circulation, or an abnormal state of the blood (such as that produced by anæsthetic agents), occasions a diminished functional activity in the Sensorial centres, this is marked by obtuseness to sensory impressions; on the other hand, in active congestion of the brain, the most ordinary external impressions produce sensations of an unbearable violence; and in that peculiar condition of the nervous system known under the name of Hysterical (§ 723), the patients often manifest the same hyperæsthesia, even when the circulation is in a feeble, rather than in an excited state.* It is remarkable that the sensibility of the mucous membranes lining the internal organs, is less exalted by the state of inflammation, than is that of most other parts; and in this arrangement we may trace a wise and beneficent provision; since, were it otherwise, the functions necessary to life could not be performed without extreme distress, whenever a very moderate amount of disorder might exist in the viscera. If a joint is inflamed, we can give it rest; but to the actions of the alimentary canal we can give little voluntary respite.

729. It is through the medium of Sensation, that we acquire a knowledge of the material Universe around us, by the psychical operations which its changes excite in ourselves. The various kinds or modes of Sensation *suggest* to us various ideas regarding the properties of matter, and these

* The influence of toxic agents introduced into the blood, in producing Anæsthesia and Hyperæsthesia, constitutes a very wide field of inquiry, which is well deserving of careful cultivation. It is remarkable that *Lead* and *Alcohol* should be capable of inducing either of these states.

properties are known to us, only through the changes which they produce in the several organs (§ 591). It is well known that instances exist, in which, from some imperfection of the organization, there is an incapacity for distinguishing colours or musical tones, whilst there is no want of sensibility to light or sound; and that some persons are naturally endowed with a much greater range of the sensory faculties, than others possess. Hence it does not seem at all improbable, that there are properties of matter, of which none of *our* senses can take immediate cognizance, and which other beings might be formed to perceive, in the same manner as *we* are sensible to light, sound, &c. Thus many animals are affected by atmospheric changes, in such a manner that their actions are regarded by Man as indications of the probable state of the weather; and the same is the case in a less degree with some of our own species, who are peculiarly susceptible of the like influences.—Now the most universal of all the qualities or properties of Matter, on which, in fact, our notion of it is chiefly founded (§ 584), is its occupation of space, producing a more or less complete *resistance* to displacement; and this quality is that through which alone any knowledge of the external world can be obtained by a large proportion of the lower Animals; *contact* between their own surface and some material body, being required to produce sensation. We shall presently see, however, that the idea of the *shape* of a body which we form from the touch, results from a very complex process, such as animals of the lower grades can scarcely be supposed to possess. There can be little doubt that, next to the mere sense of resistance, sensibility to *temperature* is the most universally diffused through the Animal kingdom; and probably the consciousness of *luminosity* is the next in the extent of its diffusion.* It is probable that the sense of *taste* (which has a close affinity to that of touch) exists very low down in the animal scale, being obviously of great importance in the selection of food; but the Anatomist has no means of ascertaining where this refinement exists, and where it does not; since the organs of taste and touch are very similar. The sense of *hearing* does not seem to be distinctly present among the Invertebrate animals, except in such as approach most nearly to the Vertebrata: it is not improbable, however, that sonorous vibrations may produce an effect upon the system of those animals which do not receive them as *sound*. The sense of *smell*, which is concerned with one of the least general properties of matter, appears to be the least widely diffused among the whole; being only possessed in any high degree by Vertebrated animals, and being but feebly present in a large proportion of these.

730. Besides the various kinds of sensibility which have been just enumerated, there are others which are ordinarily associated together, along with the sense of material resistance (and its several modifications), and the sense of temperature, under the head of Common Sensation; but

* There is good reason to believe, from observation of their habits, that many animals are susceptible of the influence, and are directed by the guidance, of *light*, whose organs are not adapted to receive true visual impressions, or to form optical images; and such would seem to be the function of the red spots, frequently seen on prominent parts of the lower Articulata and Mollusca, and even of some Radiata. Wherever these are of sufficient size to allow their structure to be examined, they are found to be largely supplied with nerves, but to be destitute of the peculiar organization which alone constitutes a true *eye*.

several of them, especially those which originate in the body itself, can scarcely be regarded in this light. Such are the feelings of hunger and thirst; that of nausea; that of distress resulting from suspended aeration of the blood; that of 'sinking at the stomach,' as it is vulgarly but expressively described, which results from strong mental emotion; the sexual sense, and perhaps some others.—Now in regard to all these, it is impossible in the present state of our knowledge to say, whether their peculiarity results from the particular constitution of the nerves that receive and convey them, or only from a modification of the impressing causes, from the particular endowments of their ganglionic centres, and from the mode in which they operate. Thus we have no evidence whether the nervous fibrils, which convey from the lungs the sense of distress resulting from deficient aeration, are of the same or of a different character from those which convey from the surface of the air-passages the sense of the contact of a foreign body. But as we know that all the trunks along which these peculiar impressions travel, do minister to ordinary sensation, whilst the nerves of truly 'special' sensation are not sensible to tactile impressions, it is evident that the probability seems in favour of the identity of the fibres which minister to these sensations, with those of the usual sensory character. We shall see that with regard to the sense of Temperature, there is strong evidence that its peculiarity depends on the speciality of the apparatus by which impressions are received at the peripheral extremities of the tactile nerves, rather than upon any peculiarity in the transmitting fibres (§ 736).

731. There are certain external agencies, which can excite changes in the Sensorium through several different channels; the sensation being in each case characteristic of the particular nerve on which the impression is made. Thus pressure, which produces through the nerves of common sensation the feeling of resistance, is well known to occasion, when exerted on the eye, the sensation of light and colours; and, when made with some violence on the ear, to produce 'tinnitus aurium.' It is not so easy to excite sensations of taste and smell, by mechanical irritation; and yet, as Dr. Baly * has shown, this may readily be accomplished in regard to the former. The sense of nausea may be easily produced, as is familiarly known, by mechanical irritation of the fauces. Electricity still more completely possesses the power of affecting all the sensory nerves with the changes which are peculiar to them; for, by proper management, an individual may be made conscious at the same time of flashes of light, of distinct sounds, of a phosphoric odour, of a peculiar taste, and of pricking sensations, all excited by the same cause, the effects of which are modified by the respective peculiarities of the instruments through which it operates.—But although there are some stimuli which can produce sensory impressions on all the nerves of sensation, it will be found that those to which any one organ is *peculiarly* fitted to respond, produce little or no effect upon the rest. Thus the ear cannot distinguish the slightest difference between a luminous and a dark object. A tuning fork, which, when laid upon the ear whilst vibrating, produces a distinct musical tone, excites no other sensation when placed upon the eye, than a slight jarring feeling. The most delicate touch cannot distinguish a substance which

* Translation of Muller's "Elements of Physiology," p. 1062 *note*.

is sweet to the taste, from one which is bitter; nor can the taste (if the communication between the mouth and the nose be cut-off) perceive any thing peculiar in the most strongly odoriferous bodies.—It may hence be inferred that no nerve of *special* sensation can, by any possibility, take-on the function of another.

2.—*Sense of Touch.*

732. By the sense of Touch, as commonly understood, is meant that modification of the common sensibility of the body, of which the Cutaneous surface is the especial seat. The Skin is peculiarly adapted for this purpose, not merely by the large amount of sensory nervous fibres which are distributed in its substance, but also by its possession of a papillary apparatus in which these nerves terminate, or rather commence. The *papillæ* are little elevations of the surface of the cutis, usually simply-conical or clavate in form (Fig. 91), but sometimes presenting numerous summits. On the palmar surface of the hand, they are arranged in rows; and they are there so numerous, that (according to E. H. Weber) as many as 81 compound, or from 150 to 200 simple papillæ, are contained within the area of a square (Paris) line. The papillæ are also very numerous, though without any definite arrangement, on the red surface of the lips, on the penis of the male, on the labia minora and clitoris of the female, and on the nipples of both sexes, but elsewhere they are scattered more widely apart. Each sensory papilla receives one or more nerve-fibres from the plexus which is formed by the inosculation of the ramifications of the cutaneous nerves (Fig. 91), and these nerve-fibres seem to terminate (at least in the papillæ of the palm of the hand and of the lips, and in the simple papillæ of the tongue, § 741) in a peculiar 'axile body,' which occupies the principal part of the interior of the papilla (Fig. 92). With regard to the nature of this body, there has been considerable discussion between Prof. Wagner, its discoverer, and Prof. Kolliker:* the former regarding it as an organ altogether *sui generis*; whilst the latter maintains that it is nothing else than a mass of homogeneous connective tissue with an external layer of imperfectly-developed elastic tissue, and that it is essentially similar to the bundles of fibrous tissue encircled

Fig. 91.

Vertical Section of the *Skin* of the palmar surface of the fore finger (treated with a solution of caustic soda), shewing the branches of cutaneous nerves, *a*, *b*, inosculating to form a terminal plexus, of which the ultimate ramifications pass into the cutaneous papillæ *c*, *c*, *c*.

* See Prof. Wagner in the Göttingen "Gelehrte Nachrichten" for Feb., 1852, and "Müller's Archiv," 1852, Heft 4, and Prof. Kolliker in "Zeitschrift für Wissenschaftliche Zoologie," June, 1852, and in his "Mikroskopische Anatomie," band ii. p. 24. See also Dalzell, in "Edinb. Monthly Journ.," March, 1853.

by elastic fibres, which are to be found in the substance of the cutis. This last view is in the main supported by Mr. Huxley, who regards the 'axile body' as formed by the continuation and increased development of the neurilemma of the nerve-tubes which enter the papilla, and as bearing a close relation to the 'Pacinian bodies.'* It was maintained by Wagner, that the papillæ which contain these bodies, and to which nerve-fibres proceed, contain no blood vessels save by coalescence with a vascular papilla; whilst the vascular papillæ which contain capillary loops (Fig. 93), constitute a distinct order, containing no nerve fibres. This, however, is denied by Prof. Kolliker; who asserts that the corpusculated papillæ of the palm of the hand often contain vessels, whilst the vascular papillæ of the lip contain nerves.

Fig. 92.

Tactile Papillæ from the Skin of the palmar surface of the fore-finger, showing the *tactile corpuscles* or 'axile bodies'; A, in the natural state; B, treated with acetic acid.

Mr. Huxley states (loc. cit.) that in the human finger he has met with corpusculated papillæ containing vascular loops, though rarely. The question must be regarded as still open to investigation; the undoubted association of capillary loops and nerve-tubes in the fungiform papillæ of the Tongue (§ 741) rendering it improbable that there should be a complete dissociation of them in the tactile papillæ of the Skin; whilst, on the other hand, the presence of a true (vascular) papillary structure where a thick epidermis has to be formed, as on the sole of the foot† or the matrix of the nail, seems to indicate that the vascular papillæ of the palm of the hand may probably be destined rather to this office, than to participate in sensa-

Fig. 93.

Capillary loops in *Cutaneous papillæ* at margin of lips.

* See his Memoir "On the Structure and Relation of the Corpuscula Tactus, in the "Quarterly Journal of Microscopical Science," vol. ii. p. 1.

† The sole of the Dog's foot is furnished with vascular papillæ, the arrangement of whose capillaries very strongly resembles that of the fungiform papillæ of the tongue; and these seem to be specially subservient to the formation of its thick cuticular covering.

bility. As the 'axile bodies' are only to be found in the papillæ of those parts which are distinguished for acuteness of tactile sensibility, we cannot regard them as *essential* to the exercise of the sense of touch; their function probably being to *intensify* tactile impressions, where delicacy of touch is peculiarly required.

733. The relative sensibility of different parts of the Skin may be in some degree judged-of by the results of the observations of Prof. E. H. Weber; whose mode of ascertaining it was to touch the surface with the legs of a pair of compasses, the points of which were guarded with pieces of cork, and then (the eyes being closed) the legs were approximated, until they were brought within the smallest distance at which they could be felt to be distinct from one another, which has been termed by Dr. Graves 'the limit of confusion.'—The following are some of the measurements thus taken.—

Point of tongue	½ of a line.	Mucous membrane of gums	9 lines.
Palmar surface of third phalanx	1 line.	Lower part of forehead . .	10 ,,
Red surface of lips	2 lines.	Lower part of occiput .	12 ,,
Palmar surface of second phalanx	2 ,,	Back of hand	14 ,,
Dorsal surface of third phalanx	3 ,,	Neck, under lower jaw . .	15 ,,
Palmar surface of metacarpus	3 ,,	Vertex . . .	15 ,,
Tip of the nose . . .	3 ,,	Skin over patella	16 ,,
Dorsum and edge of tongue .	4 ,,	——— sacrum .	18 ,,
Part of lips covered by skin	4 ,,	——— acromion . . .	18 ,,
Palm of hand . .	5 ,,	Dorsum of foot	18 ,,
Skin of cheek	5 ,,	Skin over sternum . . .	20 ,,
Extremity of great toe . .	5 ,,	Skin beneath occiput . . .	24 ,,
Hard palate . .	6 ,,	Skin over spine, in back	30 ,,
Dorsal surface of first phalanx	7 ,,	Middle of the arm . . .	30 ,,
Dorsum of hand	8 ,,	——— thigh	30 ,,

It is curious that the distance between the legs of the compasses seemed to be greater (although really so much less), when it was felt by the more sensitive parts, than when it was estimated by parts of less distinct sensibility. With the extremities of the fingers and the point of the tongue, the distance could be distinguished most easily in the longitudinal direction; on the dorsum of the tongue, the face, neck, and extremities, the distance could be recognized best when the points were placed transversely. As a general fact, it seems that the sensibility of the trunk is greater on the median line, both before and behind, and less at the sides. Differences in the temperature and weight of bodies, were, according to Prof. Weber's observations, most accurately recognized at the parts which were determined to be most sensible by the foregoing method of inquiry.*—It has been since found, however, by Prof. Valentin, who has followed-up and extended Prof. Weber's observations, that a considerable amount of individual variation exists in regard to the 'limit of confusion;' some persons being able to distinguish the points at one-half or even one-third of the distances required by others.

* See his Memoir "De Pulsu, Respiratione, Auditu, et Tactu," Lipsiæ, 1834. See also "Recherches sur la Nature, la Distribution, et l'Organ du Sens Tactile," by M. H. Belfield Lefevre, Paris, 1837; and Prof. Valentin's "Lehrbuch der Physiologie des Menschen," band ii. § 566. In the Author's article 'Touch' in the "Cyclopædia of Anatomy and Physiology," vol. iv. p. 1169, will be found a Table including the whole series of observations made by Profrs. Weber and Valentin, the *maxima* and *minima* of the latter being stated, as well as the *means*.

734. As already stated (§ 729), the only idea communicated to our minds by the sense of Touch, when exercised in its simplest form, is that of *Resistance:* and it is by the various degrees of resistance which the sensory surface encounters, of which we partly judge by the muscular sense (§ 541), that we estimate the hardness or softness of the body against which we press. It is only when either the sensory surface or the substance touched is made to change its place in regard to the other, that we obtain the additional notion of *extension* or *space;* this also being derived from the combination of the muscular with the tactile sense. By the impressions made upon the papillæ, during the movement of the tactile organ over the body which is being examined, the roughness, smoothness, or other peculiar *characters of the surface* of the latter are estimated. Our knowledge of *form*, however, is a very complex process, requiring not merely the exercise of the sense of touch, but also great attention to the muscular sensations. It is chiefly, as formerly remarked, in the *variety* of movements of which the hand of Man is capable, that it is superior to that of any other animal; and it cannot be doubted that the sense of Touch thus employed, affords us a very important means of acquiring information in regard to the external world, and especially of correcting many vague and fallacious notions which we should derive from the sense of Sight, if used alone. On the other hand, it must be confessed that our knowledge would have a very limited range, if this sense were the only medium through which we could acquire ideas. It is probably on the sensations communicated through the Touch, that the idea of the material world, as something external to ourselves, chiefly rests; but this idea is by no means a logical deduction from our experience of these sensations, being rather an instinctive or intuitive perception directly excited by them (§ 604).

735. That the conditions under which certain of the modifications of common sensation operate, are in some respects different from those of ordinary Touch, is very easily shown. Thus, the feeling of tickling is excited most readily in parts which have but a low tactile sensibility, namely, the armpits, flanks, and soles of the feet; whilst in the points of the fingers, whose tactile sensibility is most acute, it cannot be excited. Moreover, the nipple is very moderately endowed with ordinary sensibility; yet by a particular kind of irritation, a very strong feeling may be excited through it.—Again, in regard to Temperature, it is remarked by Weber, that the left hand is more sensitive than the right; although the sense of touch is undoubtedly the most acute in the latter. He states that if the two hands, previously of the same temperature, be plunged into separate basins of warm water, that in which the left hand is immersed will be felt as the warmer, even though its temperature is somewhat lower than that of the other. In regard to the sensations of heat and cold, he points out another curious fact,—that a weaker impression made on a large surface, seems more powerful than a stronger impression made on a small surface; thus, if the forefinger of one hand be immersed in water at 104°, and the whole of the other hand be plunged in water at 102°, the cooler water will be thought the warmer; whence the well-known fact, that water in which a finger can be held, will scald the whole hand. Hence it also follows, that minute differences in temperature, which are imperceptible to a single finger, are appreciated

by plunging the whole hand into the water: in this manner a difference of one-third of a degree may readily be detected, when the same hand is placed successively in two vessels. The judgment is more accurate, when the temperature is not much above or much below the usual heat of the body; just as sounds are best discriminated, when neither very acute nor very grave.

736. Some further experiments have more recently been made by Prof. Weber,* to determine whether the sense of Temperature is received through any other channel than the sensory apparatus contained in the integuments.—The first means of which he availed himself for deciding this question, was that afforded by the results of accident or surgical operations, in which a portion of skin had been left deficient. Thus, in three cases in which a large portion of the skin had been destroyed by a burn, and in which healing had not advanced so far as to renew the organ of touch, it was found that no correct discrimination could be made between two spatulas, one of them at a temperature of from 48° to 54°, the other of from 113° to 122°, which were brought into contact with the denuded surface; so that one of these patients thrice affirmed that he was being touched with the cold body, when it was warm, and the reverse. But when the spatula was in one instance made somewhat warmer, and was brought into contact with the unskinned surface, the patient felt not *heat* but *pain*.—Another means of gaining information on this point, is afforded by the ingestion or injection of a large quantity of warm or cold fluid into the stomach or intestinal canal. Thus Professor Weber states, that after drinking a tumbler of water at 32°, he felt the cold water in the mouth, in the palate, and in the pharynx, as far as the limits of the sense of touch; but the gradual passage of the cold water into the stomach could not be perceived. There was, it is true, a slight sensation of cold in the gastric region; but as it only occupied the situation of the anterior wall of the stomach, it was attributable to the abstraction of heat from the abdominal integuments in contact with this. In an opposite experiment, the author drank quickly three glasses of milk, the temperature of the first of which was 158°, that of the second 145°, whilst that of the third was intermediate between the two. The sensation of heat could not be traced lower-down than that of the cold in the previous experiment. At the moment when the fluid entered the stomach, there was a feeling which remained for some time, but which could not be distinguished as heat, being mistakeable for cold. In order to ascertain the sensation produced in the large intestine by cold water, an injection of 14 ounces of water of the temperature of 65° was thrown up the rectum; but scarcely any sensation of cold could be perceived from it. In another instance, 21 ounces of water at the same temperature were thus injected, without any resulting sensation of cold. In both these cases, on the return of the enema a few minutes afterwards, a distinct feeling of cold was experienced at the anus. When water of so low a temperature as 45½° was injected, the first feeling excited was a sensation of cold in the immediate neighbourhood of the anus, and then a feeble movement in the bowels; but a little time afterwards, there was a faint sensation of cold, especially in the anterior wall of the abdomen. This sensation, however, remained after the return of the water; and may hence be attributed to

* "Muller's Archiv.," 1849, heft iv., s. 273–283.

the abstraction of warmth from the abdominal integuments, which was proved to have taken place, the temperature of the surface being lowered 3°. So, again, if the cavity of the nose be filled with cold water, the coldness is only perceived in the parts of the cavity which are most endowed with the proper tactile sense, namely, the neighbourhood of the nostrils and of the pharynx; and it is not at all discernible in the higher part of the cavity, which is especially subservient to the olfactory sense. But when the water injected is very cold (*e. g.* 41°), a peculiar pain is felt in the upper part of the nasal fossæ, extending to the regions of the forehead and the lachrymal canals, this pain, however, is altogether different from the sense of coldness.

737. From the foregoing experiments it appears fair to conclude, that the sensory nerves have no power of receiving impressions indicative of difference of Temperature, unless those impressions are communicated through a special organ; but they afford no adequate ground for the supposition, that a set of nerve-fibres is provided for their transmission distinct from those which minister to common sensation. This conclusion is confirmed by the fact, that we cannot excite impressions of heat or cold by direct application to the trunks of nerves which we know must conduct such impressions: for the parts of the skin, immediately beneath which lie large nerve-trunks, are not more sensitive to moderate heat or cold than are any others, whilst a greater degree of either is felt as pain, not as a change of temperature. Thus, a mixture of ice and water, applied over the ulnar nerve, affects it in fifteen seconds, and produces severe pain, having no resemblance to cold, and such as cannot be excited by the same degree of cold applied to any other region. So the nerve of the tooth-pulp is equally and similarly affected by water of 43° and of 112°; either application causing a pain exactly similar to that excited by the other, or to that produced by pressure. The same is true of the impressions received through the skin itself, when they pass beyond certain limits of intensity; thus, the sensation produced by touching frozen mercury is said to be not distinguishable from that which results from touching a red hot iron.

738. The improvement in the sense of Touch, in those persons whose dependence upon it is increased by the loss of other senses, is well known; this is doubtless to be in part attributed (as already remarked) to the increased attention which is given to the sensations, and in part, it may be surmised, to an increased development of the tactile organs themselves, resulting from the frequent use of them. The process of the acquirement of the power of recognizing elevated characters by the touch, is a remarkable example of this improveability. When a blind person first commences learning to read in this manner, it is necessary to use a large type; and every individual letter must be felt for some time, before a distinct idea of its form is acquired. After a short period of diligent application, the individual becomes able to recognize the combination of letters in words, without forming a separate conception of each letter, and can read line after line, by passing the finger over each, with considerable rapidity. When this power is once thoroughly acquired, the size of the type may be gradually diminished, and thus blind persons may bring themselves, by sufficient practice, to read a type not much larger than that of an ordinary large-print Bible. The case of Saunderson, who,

although he lost his sight at two years old, became Professor of Mathematics at Cambridge, is well known; amongst his most remarkable faculties, was that of distinguishing genuine medals from imitations, which he could do more accurately than many connoisseurs in full possession of their senses. Several instances are recorded, of men who became eminent as Sculptors after the loss of their sight, and who were particularly successful in modelling portrait-busts: here, it is obvious, not merely the *tactile* but the *muscular* sensibility must be greatly augmented in acuteness by the habit of attending to it. The power of immediate recognition of individuals by the slightest contact of the hands, even after long periods of time, which most blind and deaf persons have displayed, is one of the most curious examples of the mode in which tactual perceptions will impress themselves on the memory, when they are habitually attended-to. As an example of the correct notions which may be conveyed to the mind, of the forms and surfaces of a great variety of objects, and of the sufficiency of these notions for accurate comparison, the Author may mention the case of a blind friend of his own, who has acquired a very complete knowledge of Conchology, both recent and fossil, and who is not only able to recognize every one of the numerous specimens in his own cabinet, but to mention the nearest alliances of a shell previously unknown to him, when he has thoroughly examined it by his touch. Many similar instances might be cited, one of the most remarkable being that of John Gough, who, though blind, was a noted botanical collector, and earned his livelihood as a land surveyor. Several cases are on record,* of the acquirement, by the blind, of the power of distinguishing the *colours* of surfaces which were similar in other respects; and, however wonderful this may seem, it is by no means incredible. For it is to be remembered, that the difference of colour depends upon the position and arrangement of the particles composing the surface, which render it capable of reflecting one ray whilst it absorbs all the rest; and it is quite consistent with what we know from other sources, to believe that the sense of Touch may become so refined, as to communicate a perception of such differences.†

3. *Sense of Taste.*

739. The sense of Taste is that by which we distinguish the *sapid* properties of bodies. The term, as commonly understood, includes much more than this, being usually employed to designate the whole of that knowledge of the qualities of a body (except such as is purely tactile), which we derive through the sensory apparatus situated within the mouth. But it will be hereafter shown that a considerable part of this is dependent upon the assistance of the *olfactive* sense (§ 743); which is affected, through the posterior nares, by the odorous emanations of all such bodies as are capable of giving them off; and the indications of

* Among the best authenticated of these, is that of a lady who became blind, and afterwards deaf, in consequence of an attack of confluent small pox, cited in Dr. Kitto's "Lost Senses," vol. ii. p. 79, from the "Annual Register" for 1758.—Dr. Kitto's treatise may be referred to, as containing a large collection of interesting cases of a similar description.

† For some additional details in regard to the sense of Touch, see the Author's article "Touch" in the "Cyclopædia of Anatomy and Physiology," vol. iv.

which are so combined with those of the true gustative sense, as to make an apparently-single impression upon the Sensorium. Moreover, there are certain sensorial impressions received through the organ of taste, which are so nearly allied in their character to those of *touch*, as to render it difficult to specify any fundamental difference between them: such are the *pungent* sensations produced by mustard, pepper, the essential oils, &c.; all of which substances, when applied for a sufficient length of time to any part of the cutaneous surface, produce a sensation which can scarcely be distinguished from that excited through the organ of taste, in any other way than by its inferior intensity, and by the absence of the concurrent odorous emanations. The *taste* of such substances might therefore, perhaps, be considered as the composite result of the impressions made upon the sensorium through a refined and acute *touch*, and by the effect of their odorous emanations upon the organ of *smell*. After making full allowance, however, for all such as can be thus accounted for, there remains a large class of pure *sapors*, of which we take cognizance without the assistance of smell, and which are altogether dissimilar to any tactile impressions: such are the *bitter* of quinine, the *sour* of tartaric acid, the *sweet* of sugar, the *saline* of common salt, &c. The smell can give us no assistance in distinguishing small particles of these bodies, since they are either entirely inodorous, or so nearly so as only to be recognizable through its means when in large masses; and the most refined touch cannot afford any indication of that kind of difference among them, of which we are at once rendered cognizant by taste. Of all the 'special' senses, however, that of Taste is most nearly allied to that of touch, as appears from several considerations. In the first place, the *actual contact* of the object of sense with the organ through which the impression is received, is necessary in the present case, as in the preceding. Again, it appears from the considerations formerly adduced (§ 495), that there is no special nerve of Taste; for the gustative impressions upon the front of the tongue are conveyed by the Lingual branch of the Fifth pair, whilst those made upon the back of the organ are conveyed by the Glosso-pharyngeal, both of which nerves also minister to common sensibility; and pressure on the trunk of either of these nerves gives-rise to pain, which is not the case with either the olfactory, the optic, or the auditory nerves. Moreover, the papillary apparatus, through which the gustative impressions are made upon the extremities of these nerves, is essentially the same in structure with that of the skin.

740. For the Gustative nerve-fibres to be impressed by the distinctive properties of sapid substances, it appears requisite that these substances should be brought into immediate relation with them, and that they should penetrate, in the state of solution, through the investments of the papillæ, into their substance. This would seem to be proved by the two following facts: first, that every substance which possesses a distinct taste is more or less soluble in the fluids of the mouth, whilst substances which are perfectly insoluble do not make their presence known in any other way than through the sense of touch; and, second, that if the most sapid substance be applied in a dry state to the papillary surface, and this be also dry, no sensation of taste is excited. Hence it may be inferred that, in the reception of gustative impressions,

a change is produced in the molecular condition of the nerve-fibres, or, to use the language of Messrs. Todd and Bowman, their polarity is excited, by the direct agency of the sapid matter itself. This change may be induced, however, both by electrical and by mechanical stimulation. If we make the tongue form part of a galvanic circuit, a peculiar sensation is excited, which is certainly allied rather to the gustative than to the tactile, and which does not seem to be due (as was at one time supposed) to the decomposition of the salts of the saliva. And, as Dr Baly has pointed-out,* "if the end of the finger be made to strike quickly, but lightly, the surface of the tongue at its tip, or its edge near the tip, so as to affect not the substance of the organ, but merely the papillæ, a taste sometimes acid, sometimes saline, like the taste produced by electricity, will be distinctly perceived. The sensation of taste thus induced, will sometimes continue several seconds after the application of the mechanical stimulus." On the other hand, as Wagner has truly remarked, if the surface of the tongue near the root be touched with a clean dry glass rod, or a drop of distilled water be placed upon it, a slightly bitterish sensation is produced, and this, if the pressure be continued, passes into that of nausea, and if the pressure be increased, even excites vomiting. The feeling of nausea may be excited by mechanical irritation of any part of the surface of the fauces or soft palate, and this feeling is certainly much more allied to that of taste, than to that of touch. Further, it has been observed by Henlé, that if a small current of air be directed upon the tongue, it gives rise to a cool saline taste like that of saltpetre. Thus we find that the peculiar effects of sapid substances upon the nerves of taste may be imitated to a certain extent by other agencies: and it also appears that the sensations excited by these vary according to the part of the gustative surface on which they operate, mechanical or electrical stimulation of the front of the tongue giving rise to a kind of saline taste, whilst mechanical stimulation applied to the back of the tongue and fauces excites the feelings of bitterness and nausea.—One of the conditions requisite for the due exercise of the gustative sense, is a temperature not departing far on either side from that which is natural to the body. It appears from the experiments of Prof. E. H. Weber,† that if the tongue be kept immersed for nearly a minute in water of about 125°, the taste of sugar brought in contact with it, either in powder or solution, is no longer perceived; the sense of touch, usually so delicate at the tip of the tongue, being also rendered imperfect. A similar imperfection of taste and touch was produced by immersing the tongue for the same length of time in a mixture of water and broken ice.

741. The surface of the Tongue is undoubtedly the special seat of gustative sensibility in Man; though the sense of Taste is not by any means restricted to that organ, being diffused in a less degree over the soft palate, the arches of the palate, and the fauces. It is on the tongue alone, however, that the papillary apparatus is fully developed; and its structure has been so carefully examined and described by Messrs. Todd and Bowman,‡ that little remains to be added to their account of it.—

* Translation of "Müller's Physiology," p. 1062 *note*.
† "Müller's Archiv," 1847, s. 342
‡ "Physiological Anatomy and Physiology of Man," vol. i, chap. xv.

The lingual papillæ may be divided, in the first place, into the *Simple* and the *Compound*, the former of which had previously escaped observation, through not forming any apparent projection. The *Simple* papillæ are scattered in the intervals of the compound, over the general surface of the tongue; and they occupy much of the surface behind the circumvallate variety, where no compound papillæ exist. They are completely buried and concealed beneath the continuous sheet of epithelium, and can only be detected when this membrane has been removed by maceration; they are then found to have the general characters of the cutaneous papillæ. The *Compound* papillæ are visible to the naked eye, and have been classified, according to their shape, into the *circumvallate*, the *fungiform*, and the *filiform*. The *circumvallate* or calyciform papillæ are eight or ten in number, and are situated in a V-shaped line at the base of the tongue. Each consists of a central flattened circular projection of the mucous membrane, surrounded by a tumid ring of about the same elevation, from which it is separated by a narrow circular fissure. The surface of both centre and border is smooth, and is invested by scaly epithelium, which conceals a multitude of simple papillæ. The *fungiform* papillæ are scattered singly over the tongue, chiefly upon its sides and tip. They project considerably from the surface, and are usually narrower at their base than at their summit. They contain a complex capillary plexus (Fig. 94), the terminal loops of which enter the numerous simple papillæ that clothe the surface of the fungiform body. Amidst these lie nerve-tubes, which probably have a looped arrangement;* and the epithelium which covers them is so thin, as to allow the red colour of the blood to be seen through it. In this manner they are readily distinguished from the filiform papillæ, among which they lie. The *filiform* papillæ, like the preceding, contain a plexus of capillaries, and a bundle of nerve-fibres, both terminating in loops, which enter the simple papillæ that clothe the surface of the compound body; but instead of being covered with a thin scaly epithelium, they are furnished with bundles of long pointed processes, some of which approach hairs in their stiffness and structure. These are immersed in the mucus of the mouth, and may be moved in any direction, though they are generally inclined backwards. —The simple papillæ which occur in an isolated manner, may not improbably be tactile; whilst those which are aggregated in the circumvallate and fungiform bodies, doubtless minister to the sense of Taste, this being most acute in the situations wherein they most abound. With regard, however, to the office of the filiform papillæ, there seems much reason to coincide in the opinion of Messrs. Todd and Bowman: —"The comparative thickness of their protective covering, the

Fig. 94

Capillary plexus of *fungiform papilla* of the Tongue.

* The Author, in conjunction with Messrs. Bowman, T. Wharton Jones, and Kiernan, has most carefully examined the mode of termination of the nerves in the fungiform papillæ, with the view of testing the validity of the assertion of Dr. Waller ("Phil. Trans.," 1849) that they have free truncated extremities. No such terminations, however, could be exhibited to them by Dr. Waller.

stiffness and brush-like arrangement of their filamentary productions, their greater development in that portion of the dorsum of the tongue which is chiefly employed in the movements of mastication, all evince the subservience of these papillæ to the latter function, rather than to that of taste: and it is evident that their isolation and partial mobility on one another, must render the delicate touch with which they are endowed, more available in directing the muscular actions of the organ. The almost manual dexterity of the organ, in dealing with minute particles of food, is probably provided-for, as far as sensibility conduces to it, in the structure and arrangement of these papillæ." It may be added, that the filiform papillæ of Man seem to be the rudimentary forms of those horny epithelial processes, which acquire so great a development in the tongues of the Carnivora, and which are of such importance in the abrasion of their food.

742. The simple application of a sapid substance to the gustative surface, is usually sufficient to excite the sensation; and if this application be restricted to one particular spot, we are able to recognize its place more or less distinctly. In this respect, then, the gustative impression resembles the tactile; for whilst we cannot, by our own consciousness, distinguish the parts of the retina or of the auditory apparatus on which visual or auditory impressions are made, we can make this distinction in regard to the surface which is supplied by the nerves of general sense. This determination is most precise, when the impression is made on the parts of the tongue of which the gustative sensibility is most acute, namely, the apex, sides, and posterior part of the dorsum; being probably aided, however, near the tip, by the acuteness of its tactile sensibility. The impressibility of the middle portion of the dorsum is greatly inferior; but still, when the gustative sensation has been excited there, it is referred to the spot on which the sapid substance was laid. The contact of sapid substances much more readily excites a gustative sensation, when it is made to press upon the papillæ, or is moved over them. Thus there are some substances, whose taste is not perceived when they are simply applied to the central part of the dorsum of the tongue, but of whose presence we are at once rendered cognizant by pressing the tongue against the roof of the mouth. The full flavour of a sapid substance, again, is more readily perceived when it is rubbed on any part of the tongue, than when it is simply brought in contact with it, or pressed against it. Even when liquids are received into the mouth, their taste is most completely discriminated by causing them to move over the gustative surface: thus the 'wine-taster' takes a small quantity of the liquor into his mouth, carries it rapidly over every part of its lining membrane, and then ejects it. It is not improbable that this exaltation of the usual effects is simply due to mechanical causes; the sapid particles being brought by the pressure or movement into more rapid and complete operation on the nerve-fibres, than they would be if simply placed in contact with the papillæ.

743. The impressions made upon our consciousness by a large proportion of sapid substances, are of a complex kind; being in part derived from their odorous emanations, of which we take cognizance through the organ of Smell. Of this any one may convince himself, by closing the nostrils, and inspiring and expiring through the mouth only, whilst

holding in the mouth, or even rubbing between the tongue and the palate, some aromatic substance; for its taste is then scarcely recognized, although it is immediately perceived when its effluvia are drawn into the nose. It is well known, too, that when the sensibility of the Schneiderian membrane is blunted by inflammation (as in an ordinary 'cold in the head'), the power of distinguishing flavours is very much diminished. In fact, some Physiologists are of opinion that *all* our knowledge of the *flavour* of sapid substances is received through the Smell; but this, as already shown, would not be a correct statement; and there are cases on record in which the sense of Smell has been entirely lost, without any impairment of the true sense of Taste.*

744. Taken in its ordinary composite acceptation, the sense of Taste has for its object to direct us in the choice of food, and to excite the flow of mucus and saliva, which are destined to aid in the preparation of the food for Digestion. Among the lower Animals, the instinctive perceptions connected with this sense are much more remarkable than our own; thus an omnivorous Monkey will seldom touch fruits of a poisonous character, although their taste may be agreeable; and animals whose diet is restricted to some one kind of food, will decidedly reject all others. As a general rule it may be stated, that substances of which the taste is agreeable to us, are useful in our nutrition, and *vice versâ*,† but there

* An interesting case of this kind, occurring in a Negro who had gradually lost the characteristic hue of his skin, and had acquired the fair complexion of a European (§ 274), has been put on record by Dr. J. C. Hutchinson. The Olfactory nerve seemed to be entirely paralysed, whilst the branches of the 5th Pair retained their integrity; so that, whilst the proper sense of Smell was entirely lost, a pungent burning sensation was excited by irritating vapours, and the application of snuff induced sneezing. Notwithstanding this deficiency, the sense of Taste, properly so called, did not seem to be impaired; for substances which possessed neither odour nor pungency could readily be discriminated, even though their tastes were not widely different. (See "Amer. Journ. of Med. Sci.," Jan. 1852).

† It is justly remarked by Sir H. Holland ("Medical Notes and Reflections," p. 55), that, "In the majority of instances of actual illness, provided the real feelings of the patient can be safely ascertained, his desires as to food and drink may be safely complied with. But undoubtedly much care is needful that we be not deceived as to the state of the appetites, by what is merely habit or wrong impression on the part of the patient, or the effect of the solicitation of others. This class of sensations is more nurtured out of the course of nature, than are those which relate to the temperature of the body. The mind becomes much more deeply engaged with them; and though in acute illness they are generally submitted again to the natural law, there are many lesser cases where enough remains of the leaven of habit to render every precaution needful. With such precautions, however, which every physician who can take schooling from experience will employ, the stomach of the patient becomes a valuable guide; whether it dictate abstinence from a recurrence of food; whether much or little in quantity, whether what is solid or liquid; whether much drink or little; whether things warm or cold; whether sweet, acid, or saline; whether bland or stimulating to the taste." Further, Sir H. Holland remarks: "It is not wholly paradoxical to say that we are authorized to give greatest heed to the stomach, when it suggests some seeming extravagance of diet. It may be that this is a mere depravation of the sense of taste; but frequently it expresses an actual need of the stomach, either in aid of its own functions, or indirectly (under the mysterious law just referred to) for the effecting of changes in the whole mass of blood. It is a good practical rule in such cases to withhold assent, till we find after a certain lapse of time that the same desire continues or strongly recurs; in which case it may generally be taken as the index of the fitness of the thing desired for the actual state of the organs. In the early stage of recovery from long gastric fevers, I recollect many curious instances of such contrariety to all rule being acquiesced in, with manifest good to the patient. Dietetics must become a much more exact branch of knowledge, before we can be justified in opposing its maxims to the natural and repeated suggestions of the stomach, in the state either of health or disease."

are many signal exceptions to this.—Like other senses, that of Taste is capable of being rendered more acute by education; and this on the principles already laid down in regard to Touch. The experienced wine-taster can distinguish differences in age, purity, place of growth, &c., between liquors that to ordinary judgments are alike; and the epicure can give an exact determination of the spices that are combined in a particular sauce, or of the manner in which the animal, on whose flesh he is feeding, was killed. As in the case of other senses, moreover, impressions made upon the sensory surface remain there for a certain period; and this period is for the most part longer than that which is required for the departure of the impressions made upon the eye, the ear, or the organ of smell. Every one knows how long the taste of some powerful substances remains in the mouth; and even of those which make less decided impressions, the sensations remain to such a degree that it is difficult to compare them at short intervals. Hence if a person be blindfolded, and be made to taste substances of distinct, but not widely-different flavours (such as various kinds of wine or of spirituous liquors), one after another in rapid succession, he soon loses the power of discriminating between them. In the same manner, the difficulty of administering very disagreeable medicines may be sometimes got-over, by either previously giving a powerful aromatic, or by combining the aromatic with the medicine; its strong impression in both cases preventing the unpleasant taste from exciting nausea.

4.—*Sense of Smell.*

745. The Nasal passages may be considered as having, in air-breathing Vertebrata, two distinct offices; for they constitute the portal of the Respiratory organs, and have for their office to take cognizance of the aeriform matter as it enters them, and to give warning of that which would be injurious (this being effected by the instrumentality of the Fifth pair, which receives the impressions of gaseous irritants, and excites the act of sneezing to expel them, § 520); whilst they also contain the organ of Smell, which is formed by the distribution, over a certain part of their membranous wall, of the *Olfactory* nerve, which is susceptible of being impressed by Odorous emanations. Of the nature of these emanations, the Natural Philosopher is so completely ignorant, that the Physiologist cannot be expected to give a definite account of the mode in which they produce sensory impressions. Although it may be surmised that they consist of particles of extreme minuteness, dissolved as it were in the air, and although this idea seems to derive confirmation from the fact that most odorous substances are volatile, and *vice versâ*,—yet the most delicate experiments have failed to discover any diminution in weight, in certain substances (as musk) that have been impregnating a large quantity of air with their effluvia for several years; whilst there are some volatile fluids, such as water, which are entirely inodorous.

746. The Olfactory nerves pass-down from the Olfactory Ganglion (§ 517) in the form of very numerous minute threads, which form a plexus upon the surface of the Schneiderian or pituitary membrane (Fig. 96). The filaments composing this plexus are described by Messrs. Todd and Bowman* as differing widely in structure from those of the ordinary

* "Physiological Anatomy," vol. ii p. 9.

cephalic nerves; they contain no white substance of Schwann, are nucleated and finely-granular in texture, and altogether bear a close resemblance to the gelatinous form of nerve-fibres (Fig. 95). It has been hitherto found impossible to trace the ultimate distribution of these fibres in the olfactory membrane, owing to their want of the characteristic white substance, and the absence of distinction between the nuclei of the minuter fibres and those of the nucleated tissues through which they pass; but it seems limited to the membrane covering the superior three-fourths of the septum of the nose, the superior turbinated bone and the upper half of the middle turbinated bone, and the upper wall of the nasal cavities beneath the cribriform plate of the ethmoid bone; all which surface is covered (as Messrs. Todd and Bowman have pointed-out) with a tesselated epithelium of a rich sepia-brown hue. The remainder of the nasal surface is supplied by the Fifth pair only, and is not endowed with sensibility to odours, although it is susceptible of irrita-

Fig. 95.

Fibres of ultimate ramifications of *Olfactory Nerve* of Dog.

Fig. 96.

Distribution of the *Olfactory Nerve* on the Septum Nasi. The nares have been divided by a longitudinal section made immediately to the left of the septum, the right nares being preserved entire:—1. The frontal sinus. 2. The nasal bone. 3. The crista galli process of the ethmoid bone. 4. The sphenoidal sinus of the left side. 5. The sella turcica. 6. The basilar process of the sphenoidal and occipital bones. 7. The posterior opening of the right nares. 8. The opening of the Eustachian tube in the upper part of the pharynx. 9. The soft palate divided through its middle. 10. Cut surface of the hard palate. *a.* The olfactory peduncle. *b.* Its three roots of origin. *c.* Olfactory ganglion, from which the filaments proceed that spread out in the substance of the pituitary membrane. *d.* The nasal nerve, a branch of the ophthalmic nerve, descending into the left nares from the anterior foramen of the cribriform plate, and dividing into its external and internal branch. *e.* The naso-palatine nerve, a branch of the spheno-palatine ganglion, distributing twigs to the mucous membrane of the septum nasi in its course to (*f*) the anterior palatine foramen, where it forms a small gangliform swelling (Cloquet's ganglion) by its union with its fellow of the opposite side. *g.* Branches of the naso-palatine nerve to the palate. *h.* Posterior palatine nerves. *i, i.* The septum nasi.

tion from such as are of a pungent nature; and hence it is that we cannot distinguish faint odours, unless, by a peculiar inspiratory effort, we draw the air charged with them to the upper part of the nose. In animals living in the air, it is a necessary condition of the exercise of the sense of Smell, that the odorous matter should be transmitted by a respiratory current through the nostrils, and that the membrane lining these should be in a moist state. Hence, by breathing through the mouth, we may avoid being affected by odours even of the strongest and most disagreeable kind; and in the first state of a catarrh, when the ordinary mucous secretion is suspended, the sense of Smell is blunted from this cause, as it afterwards is from the excess in the quantity of the fluid, which prevents the odoriferous effluvia from coming into immediate relation with the sensory extremities of the nerves. Hence we may easily comprehend how section of the Fifth Pair, which exerts a considerable influence over the secretions, will greatly diminish the acuteness of this sense, and will have the further effect of preventing the reception of any impressions of irritation from acrid vapours, which are entirely different in their character from true odorous impressions, and are not transmitted through the Olfactory nerve (§ 520).

747. The importance of the sense of Smell among many of the lower Animals, in guiding them to their food, or in giving them warning of danger, and also in exciting the sexual feelings, is well known. To Man its utility is comparatively small under ordinary circumstances; but it may be greatly increased when other senses are deficient. Thus, in the well known case of James Mitchell, who was blind, deaf, and dumb, from his birth, it was the principal means of distinguishing persons, and enabled him at once to perceive the entrance of a stranger. It is recorded that a blind gentleman, who had an antipathy to cats, was possessed of a sensibility so acute in this respect, that he perceived the proximity of one that had been accidentally shut-up in a closet adjoining his room. Among savage tribes, whose senses are more cultivated than those of civilized nations, more direct use being made of the powers of observation, the scent is almost as acute as in the lower Mammalia: thus it is asserted by Humboldt, that the Peruvian Indians in the middle of the night can distinguish the different races, whether European, American Indian, or Negro; and the Arabs of the Great Desert are said to be able to distinguish the smell of a fire thirty miles off.—The agreeable or disagreeable character assigned to particular odours, is by no means constant amongst different individuals. Just as many of the lower Animals pass their whole lives in the midst of odours that are to Man (in his civilized condition at least) in the highest degree revolting, and will even refuse to touch food until it is far advanced in putridity, so do we find that men who are compelled by circumstances to live upon putrescent food, come at last to relish it most when it is furthest advanced in decomposition (§ 62), and the most refined epicures among highly-civilized communities seem to find pleasure in similar odours and savours, which, to ordinary tastes, are anything but agreeable.—As to the length of time during which impressions made upon the organ of Smell remain upon it, no certain knowledge can be obtained. It is difficult to say when the effluvia themselves have been completely removed from the nasal passages, since it is not unlikely that the odorous particles (supposing such to exist) are

absorbed or dissolved by the mucous secretion; it is probably in this manner that we may account for the fact, well known to every medical man, that the cadaverous odour is frequently experienced for many days after a post-mortem examination.*

5.—*Sense of Vision.*

748. The objects of this sense are bodies from which Light proceeds, either because they are luminous in themselves, or because they reflect the light that proceeds from other bodies. Whether their light is transmitted by the actual *emission* of luminous particles, or by the propagation of *undulations* analogous to those of sound, is a question that has been long keenly debated amongst Natural Philosophers, but it is of little consequence to the Physiologist *which* is the true solution, since he is only concerned with the laws according to which the transmission takes place, which are the same on both theories. These laws it may be desirable here briefly to recapitulate.

749. Every point of a luminous body sends-off a number of rays, which diverge in every direction, so as to form (as it were) a cone, of which the luminous point is the apex. So long as these rays pass through a medium of the same density, they proceed in straight lines; but if they enter a medium of different density, they are *refracted* or bent,—*towards* the perpendicular to the surface at the point at which they enter, if they pass from a rarer into a denser medium,—and *from* the perpendicular, when they pass from a denser medium into a rarer. It is easily shown to be a result of this law, that, when parallel rays passing through air fall upon a convex surface of glass, they will be made to converge, so as to meet at the opposite extremity of the diameter of the circle, of which the curve forms part. If, instead of continuing in the glass, they pass-out again, through a second convex surface, of which the direction is the reverse of the first, they will be made to converge still more, so as to meet in the centre of curvature. Rays which are not parallel, but which are diverging from a focus, are likewise made to converge to a point or focus, but this point will be more distant from the lens, in proportion as the object is nearer to it, and the angle of divergence consequently greater. The rays diverging from the several points of a luminous object, are thus brought to corresponding foci; and the places of all these foci hold exactly the same relation to each other, with that of the points from which the rays diverged; so that a perfect image of the object is formed upon a screen held in the focus of the lens. This image, however, will be inverted; and its size, in proportion to that of the object, will depend upon their respective distances from the lens. If their distances be the same, their size will also be the same; if the object be distant, and the image near, the latter will be much the smaller: and *vice versâ*.

750. There are two circumstances, however, which interfere with the perfection of an image thus formed by a convex lens. The one is, that, if the lens constitute a large part of the sphere from which it is taken, the rays which fall near its margin are not brought to a focus at the same point with those which pass through its centre, but at a point nearer the

* This may partly be attributed also to the effluvia adhering to the dress. It has been remarked that *dark* cloths retain these more strongly than *light*.

lens. This difference, which must obviously interfere greatly with the distinctness of the image, is termed *Spherical Aberration;* it may be corrected by the combination of two or more lenses, of which the curvatures are calculated to balance one another, in such a manner that all the rays shall be brought to the same focus, or by diminishing the aperture of the lens by means of a stop or diaphragm, in such a manner that only the central part of it shall be used. The latter of these methods is the one employed, where the diminution in the amount of light transmitted is not attended with inconvenience. The nearer the object is to the lens (and the greater, therefore, the angle of divergence of its rays), the greater will be the spherical aberration, and the more must the aperture of the diaphragm be reduced in order to counteract it.—The other circumstance that interferes with the distinctness of the image, is the unequal refrangibility of the differently-coloured rays, which together make-up white or colourless light; the violet being more bent from their course than the blue, the blue more than the yellow, and the yellow more than the red; the consequence of which will be, that the violet rays are brought to a focus much nearer to the lens than the blue, and the blue nearer than the red. If a screen be held to receive the image in the focus of any of the rays, the others will make themselves apparent as fringes round its margin. This difference is termed *Chromatic Aberration.* It is corrected in practice, by combining together lenses of different substances, of which the *dispersive* power (that is, the power of separating the coloured rays) differs considerably. This is the case with flint and crown-glass, for instance,—the dispersive power of the former being much greater than that of the latter, whilst its refractive power is nearly the same: so that, if a convex lens of crown-glass be united with a concave of flint whose curvature is much less, the dispersion of the rays effected by the former will be entirely counteracted by the latter, which diminishes in part only its refractive power.

751. The Eye may be regarded as an optical instrument of great perfection, adapted to produce, on the surface of the Retina, a complete image or picture of luminous objects brought before it; in which the forms, colours, lights and shades, &c. of the object are all accurately represented. By the different refractive powers of the transparent media through which the rays of light pass, and by the curvatures given to their respective surfaces, both the Spherical and Chromatic aberrations are corrected in a degree sufficient for all practical purposes; so that, in a well-formed eye, the picture is quite free from haziness and from false colours. The power by which it adapts itself to variations in the distance of the object,—so as to form a distinct image of it, whether it be six inches, six yards, or six miles off,—is extremely remarkable, and cannot be regarded as hitherto completely explained. It is obvious that, if we fix upon any distance as that for which the eye is naturally adjusted (say 12 or 14 inches, the distance at which we ordinarily read), the rays proceeding from an object placed nearer to the eye than this, would not be brought to a focus upon the retina, but would converge towards a point behind it; whilst, on the contrary, the rays from an object at a greater distance would meet before they reach the retina, and would have again diverged from each other when they impinge upon it; so that, in either case, vision would be indistinct. Now two methods of adaptation suggest

themselves to the Optician. Either he may vary the distance between the refracting surface and the screen on which the image is formed, in such a manner that the latter shall always be in the focus of the converging rays; or, the distance of the screen remaining the same, he may vary the convexity of his lens, in such a manner as to adapt it to the distance of the object.—The mode in which this adaptation is effected in the Human Eye has not yet been clearly made-out; and many hypotheses have been put forward respecting it. According to the calculations of Olbers, based on the ascertained refractive powers of the media of the eye, the difference between the focal distances of the images of two objects, the one so far off that its rays are parallel, and the other at the distance of only four inches from the eye, is about 0·143 or one-seventh of an inch; but as the usual range of distinct vision does not extend to objects brought within six or seven inches, the amount of change required in the relative places of the refracting bodies and the retina, would not ordinarily exceed a line. It has been thought that this change might be produced by an alteration in the convexity of the cornea, or by an elongation of the globe of the eye generally, or by both methods in combination; which alterations, it was supposed, might be effected by the action of the muscles of the eye ball. But no such changes have been detected by the most careful measurement; and it cannot be shown *how* any contractile action of the muscles of the eye-ball could produce an elongation of the eye, since their tendency would be (when acting altogether) to draw it backwards into its socket, or, this being prevented by the fascia and cushion of fat against which its posterior side rests, to flatten the globe against this, rather than to increase its projection. There is much more ground for the belief, however, that a change of place is effected in the crystalline lens, by the action of the ciliary muscle and the erectile tissue of the ciliary processes; for, although no such change can be demonstrated by observation, yet it can be shown that the contraction of the ciliary muscle would tend to draw the lens forwards; and the fact that this muscle is peculiarly powerful in the predaceous Birds, which are distinguished for their great range of vision, and which have, in their circle of osseous sclerotic plates, an unusually firm point of attachment for it, is a strong argument in favour of this doctrine.* Further, the almost entire loss of the power of adapting the eye to distances, which is experienced after the removal of the Crystalline lens in the operation for Cataract, is a marked indication that some change in the place or figure of this body is the principal means whereby the ordinary adaptation is effected; and although it has been suggested that an alteration in the *figure* of the lens might participate in the result, yet no means can be pointed out as competent to produce it; so that, as far as we can at present judge, a change in the *place* of the lens is the sole means of adapting the eye to distinct vision at varying distances.—It is certain that the condition of *repose* is that of vision for *distant* objects, no fatigue being experienced from the prolonged direction of the eye to these; whilst the employment of the visual power upon *near* objects for some time, is accompanied with a sense of *effort*, and is followed by fatigue. The move-

* See on this subject, Messrs. Todd and Bowman's "Physiological Anatomy," vol. ii. p. 27; and Dr. Clay Wallace on "The Adjustment of the Eye to Distances," New York, 1851.

ent which effects the change of place of the crystalline lens, is performed in obedience to Volition and is guided by sensation; yet we are not conscious of performing it, all that we *will* being the *result;* and thus we have another apposite illustration of the really automatic nature of what are termed 'voluntary movements' generally (§ 548).

752. When both eyes are fixed upon an object, their axes converge so as to meet in it, and the degree of convergence is of course altered by variations in the distance of the object; since, when the object is very remote, the optic axes are virtually parallel, whilst its approach causes them to incline towards each other, and this the more rapidly as the object is brought nearer, the increase being the greatest when it has arrived within the ordinary distance of distinct vision. Here, again, we have an example of the automatic nature of voluntary actions; for the convergence of the eyes that may be produced by this gradual approximation of an object on which the eyes are kept-fixed by an exercise of the Will, far exceeds that which most individuals can induce by an effort made directly for the purpose; and if, when an object has thus been gradually approximated to within a few inches of the nose, the voluntary fixation be intermitted and the optic axes be allowed to regain their parallelism, they can seldom be brought to converge again upon it, without repeating the whole process.—It has been thought, from the close accordance between the changes required for the adaptation of the eyes to distinct vision at different distances, and the alterations in the direction of the optic axes which are required to bring the two eyes to bear upon objects at varying degrees of proximity or remoteness, that the former of these movements is in some degree dependent upon the latter, or, at any rate, that the two proceed from a common motor impulse. But that the convergence of the axes is not itself in any way the occasion of the alteration of the focus of the eye, is shown by these two facts, first, that the adaptation is as perfect in a person who only possesses or uses one eye, as it is when both are employed; and second, that some persons possess the power of altering the focus of the eyes by an effort of the will, whilst the convergence remains the same.—In regard to the adaptation of the eyes to varying distances, it is further to be remarked, that, when an object is being viewed as near to the eye as it can be distinctly seen, the pupil contracts in a considerable degree. The purpose of this change, is evidently to exclude the outer rays of the cone or pencil, which, from the large angle of their divergence, would fall so obliquely on the convex surface of the eye as to be much affected by the spherical aberration, and thus to allow the central rays only to enter the eye, so as to preserve the clearness of the image: the principle being exactly the same as that on which the optician applies a *stop* behind his lenses, which reduces their aperture in proportion to the shortness of their focal distance. The channel through which this action is effected, is evidently the same as that through which the convergence of the eyes is produced,—namely, the inferior branch of the Third pair of nerves, to the action of which, the sensations received through the retina seem to afford the immediate stimulus, in the same manner as they do to the ordinary variation in the diameter of the pupil under the influence of light, but the voluntary determination to fix the vision upon the object, is the original source of the action.

753. The ordinary forms of defective vision, which are known under

the names of *Myopia* and *Presbyopia*, or 'short-sightedness' and 'long-sightedness,' are entirely attributable to defects in the optical adaptation of the eye. In the former, its refractive power is too great; the rays from objects at the usual distance are consequently brought too soon to a focus, so as to cross one another and diverge before they fall upon the retina; whilst the eye is adapted to bring to their proper focus on the retina, only those rays which were previously diverging at a large angle, from an object in its near proximity. Hence a 'short-sighted' person, whose nearest limit of distinct vision is not above half that of a person of ordinary sight, can see minute objects more clearly: his eyes having, in fact, the same magnifying power which those of the other would possess, if aided by a convex glass that would enable him to see the object distinctly at the shortest distance. But as the myopic structure of the eye incapacitates its possessor from seeing objects clearly at even a moderate distance, it is desirable to apply a correction; and this is done, by simply interposing between the object and the eye a *concave* lens, of which the curvature is properly adapted to compensate for the excess of that of the organ itself.—On the other hand, in the presbyopic eye, the curvature and refractive power are not sufficient to bring to a focus, on the retina, rays which were previously divergent in a considerable or even in a moderate degree; and indistinct vision in regard to all near objects is, therefore, a necessary consequence, whilst distant objects are well seen. This defect is remedied by the use of *convex* lenses, which make-up for the deficiency of the curvature.—We commonly meet with myopia in young persons, and with presbyopia in old; but this is by no means the invariable rule; for even aged persons are sometimes 'short-sighted,' and 'long-sightedness' is occasionally met-with amongst the young. In choosing spectacles for the purpose of correcting the errors of the eye, it is of great consequence not to make an over-compensation; for this has a tendency to increase the defect, besides occasioning great fatigue in the employment of the sight. It may be easily found when a glass of the right power has been selected, by inquiring of the individual whether it alters the apparent size of the objects, or only renders them distinct. If it alter the size (increasing it, if it be a convex lens, and diminishing it, if it be a concave), its curvature is too great; whilst if it do not disperse the haze, it is not sufficiently powerful. In general it is better to employ a glass which somewhat under-compensates the eye, than one whose curvature is at all too high; since, with the advance of years in elderly persons, a progressive increase in power is required; whilst, as young persons grow-up to adult age, they should endeavour to dispense with the aid of spectacles. —Many other interesting inquiries, respecting the action of the Eye as an optical instrument, suggest themselves to the Physical philosopher; but the foregoing are the chief in which the Physiologist is concerned; and we shall now proceed, therefore, to consider the share which the Nervous apparatus performs in the phenomena of vision.

754. The Optic Nerve, at its entrance into the eye, divides itself into numerous small fasciculi of ultimate fibrils, and these appear to spread themselves out, and to inosculate with each other by an exchange of fibrils, so as to form a net-like plexus, which constitutes the inner layer of the Retina (Fig. 96, 7) in immediate contact with the 'limitary membrane,' (8). There is considerable difficulty, however, in the precise

determination of the course of the nerve-fibres in the Retina, on account of their minute size and the alteration in their characters. Although uniformly much smaller than ordinary nerve fibres, they present considerable diversities in size (Fig. 98, 1, 2); the largest of them being only about 1-6000th of an inch in diameter, whilst the smallest are no more than from 1-30,000th to 1-50,000th of an inch. Notwithstanding the statement of Prof. Kolliker, that they closely resemble the finest nerve-tubes in the central organs, he has not been able to demonstrate their tubular character; and it is considered by Mr. Bowman that, like the fibres of the Olfactive tract (§ 746), they consist of axis-cylinders without sheaths. Perhaps the fact may rather be, that they are in that early stage of development, in which the components of a complete tubular fibre have not yet been differentiated.—Externally to the stratum of nerve-fibres, which may be called the Optic layer, is a vesicular stratum (Fig. 97, 6), which consists of a finely-granular matrix, wherein are imbedded nerve-cells exactly resembling those of the Encephalon, and having, like them, a variable number of processes, some of which appear to become continuous with the fibres about to be described. It is to these fibrous and vesicular layers of the Retina, which together make-up the analogue of the cortical substance of the Cerebrum, that the principal supply of blood is distributed, by the minute capillary net-work (Fig. 99) which is spread-out through their substance.—The principal part of the thickness of the Retina, however, is made-up of a series of layers whose structure has until lately been completely misunderstood; and though their real character cannot be regarded as yet fully elucidated, yet a great step has been made in advance by the researches of H. Muller and Kolliker.* These layers, as seen in a vertical section (Fig. 97), succeed each other from within outwards as follows:—In contact with the vesicular layer (6) is a layer of finely-granular matter of a greyish hue, in which an indistinct radiating fibrous appearance is seen; next is a layer of definite granules (4), which seem like minute cells closely investing nuclei; outside this is another layer (3), in which the appearance of radiating fibres

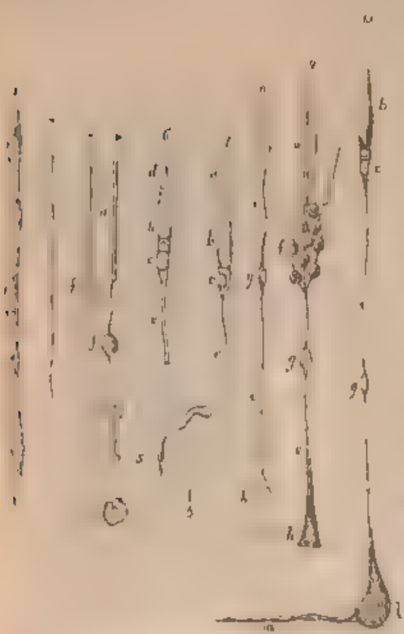
Fig. 97.

Vertical Section of *Retina* of the Human Eye:—1, bacillar layer; 2, outer granular layer; 3, intermediate fibrous layer; 4, inner granular layer; 5, finely granular grey layer; 6, layer of nerve-cells; 7, layer of fibres of optic nerve; 8, limitary membrane.

* See the memoir of the former, 'Zur Histologie des Netzhaut,' in "Kolliker and Siebold's Zeitschrift," 1851; and the "Mikroskopische Anatomie," band ii. § 274, and the "Manual of Human Histology" (Sydenham Society's Ed.), vol. ii. pp. 368-382, of the latter.—See also Mr. Bowman's "Lectures on the Parts concerned in the Operations on the Eye," p. 81, and Todd and Bowman's "Physiological Anatomy," vol. ii. pp. 28-30.

is more distinct; this, again, is succeeded by another granular layer (2) resembling the preceding, and outside all these is the layer (1) of 'cones' and 'rod-like' bodies, which has long been known as 'Jacob's membrane.' This last has been supposed to be entirely disconnected, both structurally and functionally, from the proper nervous apparatus of the Retina; but recent investigations have made it probable that it really forms part of it. For the 'rods' or 'staff like' bodies (Fig. 98, *a a*), may be traced into continuity with the granules (*f, f*) of the outer granular layer, sometimes immediately, sometimes by the intervention of a fine fibrous prolongation; and from the granules of the outer layer, fine fibres (*e, e*) may be traced towards those of the inner layer (*g, g*). So, again, the 'cones' (*b, b*), whose outer extremities (*d, d*) are often seen on the external surface as 'rods,' may be traced into continuity with the granular layers (*f, g*,) by the intermediation of fine fibres (*e, e*). And from the outer granular layer, similar very delicate fibres are found to pass towards the vesicular layer, where some of them appear to come into absolute continuity with the radiating prolongations of the nerve-cells (10, *l*), whilst others pass through the vesicular layer, and expand into trumpet-shaped terminations (9, *h*), in the stratum of optic fibres. The effects of reagents, moreover, on these elements, are such as to increase this probability. It is to be remarked especially of the rod-like bodies, that they are very speedily and remarkably altered by the contact of water, which causes them to undergo contortions and irregular bulgings and contractions (5).—Although the general direction of the fibrous elements of the Retina itself (as distinguished from those of the expansion of the Optic Nerve) is *radial* as regards the globe of the eye, or *vertical* as regards any part of the surface of the membrane yet there are situations in which the rod like bodies are directed so

FIG. 98.



Elements of *Human Retina*.—1, large fibre of optic nerve. 2, very fine fibre of the same. 3, rod with a granule *f* attached. 4, a similar rod with a fine fibrous prolongation, connecting it with the granule. 5, portions of rods altered by the action of water. 6, 7, two cones *b b*, with their nuclei *c c*, their bacillar portions *d d*, and their fine fibrous prolongations *e e*. 8, rod along fibre *e e*, with granule of outer layer *g*, and subdividing in the [illegible] layer, as well as in the optic layer *h*. 9, connection of rods *a*, with granules of inner layer *f*, granule of outer layer *g*, and expansion *h* of the fibre proceeding from the latter in the optic layer at *h*. 10, similar connection of cone *b c*, with granule *g*, and with nerve-cell *l*, which has another fibrous prolongation *m*.

obliquely, as to present quite an imbricated arrangement upon the external surface (Fig. 100).

Fig. 99

Distribution of Capillaries in the Vascular layer of the *Retina*

Fig. 100.

Part of external surface of *Retina of Frog*, showing the imbricated arrangement of the extremities of the rods of 'Jacob's Membrane.'

755 There are two spots in the Retina, in which the arrangement of the foregoing components is essentially different, and from these differences important physiological conclusions may be drawn. One of these is the slight eminence at which the Optic nerve enters, which is a little below and internal to the posterior extremity of the axis of the eye; here all the other elements than the nerve-fibres are entirely wanting. The other is the 'yellow spot of Soemmering,' which is situated in the exact centre of the retina; here the stratum of optic-fibres is wanting, the nerve-cells being in immediate contact with the limitary membrane; the granular layer is deficient in the centre, so that the pigment of the choroid is visible through it; but the bacillar layer is everywhere continuous, the ordinary 'rods,' however, having their places entirely occupied by the 'cones,' whose extremities abut upon the external surface, instead of being removed from it as elsewhere.—Now it is not a little remarkable, that the point of the entrance of the Optic nerve should be deficient in the power of receiving distinct visual impressions (§ 772), whilst the 'yellow-spot' is the most sensitive portion of the entire Retina. And hence it seems unequivocally to follow, that these impressions cannot act primarily upon the nerve-fibres;—a conclusion which harmonizes with the fact, that the fibres of the optic nerve are superimposed upon each other in the stratum which they form, in such numbers that it is not conceivable that they should be the primary recipients of luminous impressions, since their transparency must allow rays of light to penetrate from one portion of the layer to another. The bacillary layer was formerly regarded as a reflecting apparatus, having for its purpose to stop the further passage of light, and to intensify its influence on the true retina; but since its connection with the proper nervous elements of the retina has been established, there seems much ground for believing (with Prof. Kolliker) that its rods and cones are the primary recipients of luminous impressions, and that they communicate their condition to the fibres of the optic nerve, by means of their own delicate fibrous prolongations, which

seem to come into more or less direct connection with its ultimate ramifications. This supposition derives confirmation from the remarkable fact, that the diameter of the rods bears a very close correspondence with the dimensions of the retinal images of the smallest objects of which we can take cognizance (§ 756). And it harmonizes well, also, with the idea recently put-forth, that the obliquity of the rods is such as to make them all point towards 'the centre of direction' of the visual rays (§ 759); and that it is through this instrumentality, that we are guided in our appreciation of the relative directions of different objects, as Articulated animals probably are by the impressions made on the individual ocelli of their compound eyes (PRINC. OF COMP. PHYS., § 718), since the object whose rays pass-down any one of these, must always be in the direction of its axis.*

756. The *limits* of Human Vision, as regards the minuteness of the objects of which it can take cognizance, have been investigated by Prof. Ehrenberg, with the view of calculating the ultimate power of the Microscope.† In opposition to the generally-received opinion, Ehrenberg arrived at the conclusion that, in regard to the extreme limits of vision, there is little difference amongst persons of ordinarily good sight, whatever may be the focal distance of their eyes. The smallest square magnitude usually visible to the naked eye, either of white particles on a black ground, or of black upon a white or light-coloured ground, is about the 1-405th of an inch. It is possible, by the greatest condensation of light, and excitement of the attention, to recognize magnitudes between the 1-405th and 1-540th of an inch; but without sharpness or certainty. Bodies which are smaller than these, cannot be discerned with the naked eye when single; but may be seen when placed in a row. Particles which powerfully reflect light, however, may be distinctly seen, when not half the size of the least of the foregoing; thus, gold dust‡ of the fineness of 1-1125th of an inch, may be discerned with the naked eye in common daylight. The delicacy of vision is far greater for *lines* than for mere points; since opaque threads of 1-4900th of an inch in diameter (about half the diameter of the Silk-worm's fibre) may be discerned with the naked eye, when held towards the light. The degree in which the *attention* is directed to them, has a great influence on the readiness with which very minute objects can be perceived; and Ehrenberg remarks that there is a much greater difference amongst individuals in this respect, than there is in regard to the absolute limits of vision. Many persons can distinctly see such objects, when their situation is exactly pointed-out to them, who cannot otherwise distinguish them; and the same is the case with persons of acuter perception, with respect to objects at distances greater than those at which they can see most clearly. "I myself," says Ehrenberg, "cannot see 1-2700th of an inch, black or white, at twelve inches' distance; but having found it at from four or five inches' distance, I can remove it to twelve inches, and still see the object plainly." Similar phenomena are well known in regard to a balloon or a faint star in a clear sky, or a ship

* See the very ingenious "Essai sur les Phosphènes," by Dr. Serre, Paris, 1853.

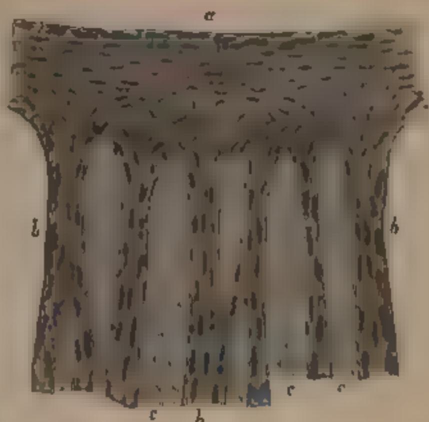
† Taylor's "Scientific Memoirs," vol. i. p. 576.

‡ Ehrenberg mentions that he obtained the finest particles of gold, by scraping gilt brass; by filing pure gold, he always obtained much coarser particles.

in the horizon we easily see them after they have been pointed out to us, but the faculty of readily descrying objects depends on the habit of using the eyes in search of them, and of attending to the sensory impressions thus received (§ 775).

757. The amount of light admitted to the Eye is regulated by the contraction and dilatation of the Pupil, the smallest diameter of which is about 1-20th, and its largest about 1-3rd of an inch. The muscular structure of the Human *Iris* is entirely of the non-striated kind, being composed of the elongated fibre-cells with staff-shaped nuclei which are characteristic of that variety. Part of these are so disposed as to form a circular sphincter (Fig. 101, *a*), which can be readily seen in the iris of the white rabbit or in the blue iris of man from which the uvea has been removed, immediately surrounding the pupillary margin to the breadth of about one-third of a line. The fibres of this sphincter are not absolutely parallel, especially at the outer margin, where they seem to become continuous with those of the radiating fasciculi (*b*, *b*), which may be traced from this sphincter (though usually with difficulty) to the outer margin of the iris, sometimes anastomosing with each other in their course.* The contraction of the annular fibres, whereby the diameter of the pupil is *diminished*, is effected, as already explained (§ 512), through the instrumentality of the Third pair of nerves; the contraction of the radiating fibres, on the other hand, whereby the pupil is *dilated*, is under the government of the cervical portion of the Sympathetic, being called forth (as MM. Budge and Waller have shown†) by irritation of the trunk of the Sympathetic in the neck by the magneto-electric apparatus, whilst a section of this nerve produces a permanent contraction of the pupil, the action of the Third pair being then no longer antagonized. It appears from other experiments, that the fibres through which this movement is effected, pass through the Gasserian ganglion, and are distributed to the eye by the ophthalmic branch of the Fifth pair (§ 492). The contraction of the Pupil answers

Fig. 101.



Muscular structure of the Iris of a White Rabbit:—*a*, sphincter of the pupil; *b*, *b*, radiating fasciculi of dilator muscle; *c*, *c*, connective tissue with its corpuscles.

* See Prof. Kölliker's "Mikroskopische Anatomie," band ii. § 272, and Jos. J. Lister's "Observations on the Contractile Tissue of the Iris," in "Quart. Journ. of Microscop. Science," vol. i. p. 8.

† "Gazette Médicale," 1851, Nos. 41, 44.

the purpose, as we have seen, not merely of excluding superfluous light from the eye, but also of cutting-off the most divergent rays, when the object is brought near the refracting surface (§ 752).

758. The sense of Vision depends, in the first place, on the excitement of our sensational consciousness by the ocular picture impressed upon the retina, which represents the outlines, lights and shades, colours, and relative positions, of the objects before us; and all the ideas respecting the real forms, distances, &c., of bodies, which we found upon these data, are derived through the perceptions, either instinctively or experientially suggested by sensations. Many of these ideas are derived through the combination, in our minds, of the Visual perceptions, with those derived from the sense of Touch. Thus, to take a most simple illustration, the idea of *smoothness* is one essentially tactile; and yet it constantly occurs to us, on looking at a surface which reflects light in a particular manner. But, if it were not for the association which experience leads us to form, of the connection between *polish* as seen by the *eye*, and *smoothness* as felt by the *touch*, we should not be able to determine, as we now can do, the existence of both these qualities, from an impression communicated to us through either sense singly.—The general fact that, in Man, the greater part of those notions of the external world, by which his actions in the adult state are guided, are acquired by the gradual association of the two sets of perceptions derived through the Sight and through the Touch, is substantiated by amply sufficient evidence; this being chiefly derived from observations made upon persons born blind, to whom sight has been communicated by an operation, at a period of life which enabled them to give an accurate description of their sensations. The case recorded by Cheselden is one of the most interesting of these. The youth (about twelve years of age), for some time after tolerably-distinct vision had been obtained, saw everything *flat* as in a picture, simply receiving the consciousness of the impression made upon his retina, and it was some time before he acquired the power of judging, by his sight, of the real forms and distances of the objects around him. An amusing anecdote recorded of him, shows the complete want which there is in Man, of any natural or intuitive connection between the ideas formed through visual and through tactile sensations. He was well acquainted with a Dog and a Cat by *feeling*, but could not remember their respective characters when he *saw* them; and one day, when thus puzzled, he took-up the Cat in his arms, and felt her attentively, so as to associate the two sets of ideas, and then, setting her down, said "So puss, I shall know you another time." —A similar instance has come under the Author's own knowledge, but the subject of it was scarcely old enough to present phenomena so striking. One curious circumstance was remarked of him, which fully confirms (if confirmation were wanting) the view here given. For some time after his sight was tolerably clear, the lad preferred finding his way through his father's house (to which he had been quite accustomed when blind) by touch rather than by sight, the use of the latter sense appearing to perplex instead of assisting him; but, when learning a new locality, he employed his sight, and evidently perceived the increase of facility which he derived from it.*—The actions performed by many new-born

* The question has been proposed, whether a person born blind, who was able by the sense of Touch to distinguish a cube from a sphere, would, on suddenly obtaining his

animals (§ 604) do not constitute any valid objection to the view that such visual perceptions are for the most part *acquired* by Man; for all that is indicated by them is, that certain sensations give-rise to movements adapted to supply the wants to which they relate; and they do not afford any proof that definite notions, such as we entertain, of the forms and properties of external objects, are possessed by the animals which exhibit them. We shall now examine, a little more in detail, into the means by which we gain such notions, and the data on which they are founded.

759. The first point to be determined, is one which has been a fruitful source of discussion,—the cause of *erect vision*, the picture upon the retina being inverted; and with this is connected the general question of the origin of our *Sense of Direction*.—The difficulty which has been raised in regard to the former subject, is rather apparent than real; being founded on an erroneous notion of the nature of the Visual sense. For it seems to have been supposed that we *look at* the retinal picture with the 'mind's eye,' just as we look at the picture formed by a Camera with the bodily eye; and that our consciousness must be therefore impressed by its discordance with the information which we receive through our sense of Touch. Some philosophers, indeed, have actually gone so far as to assert, that the Infant must at first see everything inverted, and that the erectness of visual objects is only learned by the corrective experience gained by touching and handling them. But such is clearly not the case, for the visual perception is obviously not a mere *transfer* of the sensorial impression, but is a *mental state excited by it*, and therefore related to it as an effect to its cause; and we know no reason why it should be *less natural* for the retinal picture to *suggest to the mind* the notion of *erect* position, than for it to have the contrary effect. Moreover, it will appear from recent investigations to be hereafter detailed (§ 773), that there is in the eye a common 'centre of direction,' through which all lines must pass, that are drawn from any points of an external object to the corresponding points of its retinal image;* and that we intuitively refer the cause of the excitation of any spot of the retina by a luminous impression, to an objective source in the 'line of direction' which passes from that spot through the centre of direction; so that, in virtue of this 'law of visible direction,' as all the lines of direction cross each other both vertically and laterally, the formation of an inverted image upon our retina suggests to our minds the representation of the object in its erect position, and the same reversal takes-place also in regard to its two sides, which are transposed in the retinal picture. A peculiar arrangement of the receptive

sight, be able to distinguish them by the latter sense. This question was answered by Locke in the negative, and, as appears from the facts above stated, with justice.

* With regard to the precise situation of this 'centre of direction,' there is a want of accordance among those who have attempted to determine it, some having placed it in the centre of the pupil, others in the centre of the crystalline lens, others at various distances between this and the centre of the globe, and others (among them Sir D. Brewster) in the centre of the globe. This last notion, and the 'law of visible direction' founded upon it,—which affirms that every object is seen in the direction of the perpendicular or radius to every point of the retina which is impressed,—is so manifestly wrong, that it is difficult to conceive how it could ever have been entertained by men of science. The experimental investigations of Dr. Serre (§ 773) lead him to regard the centre of the crystalline as the 'centre of direction.'

apparatus, which seems to be subservient to this mental appreciation of direction, has been already noticed (§ 755).

760. The cause of *Single Vision with the two Eyes* has, in like manner, been the subject of much discussion; and here, too, the difficulty is rather apparent than real, having for its foundation the idea that the mind looks at the two retinal pictures as at two separate objects, instead of being impressed by a certain state of the Sensorium, which may be excited through the instrumentality of either eye, or through that of both in combination. Some have even asserted, under the influence of this idea, that we do not really employ both eyes simultaneously, but that the mind is affected by the image communicated by one only; which might seem to be confirmed by the fact heretofore mentioned (§ 592), respecting the alternate use of the two eyes, when they are looking through two differently coloured media. But of this assertion a complete disproof is afforded by the knowledge we now possess (§ 761), that our appreciation of the solid forms of bodies depends on the combination, *by the Mind*, of the images simultaneously suggested by the two pictures; and that our knowledge of distances is in great part obtained in like manner.—Attempts have been made to explain the phenomena of Single Vision by the peculiar decussation of the Optic Nerves formerly described (§ 523); it being supposed that only one Optic Ganglion would be affected by an impression made upon both Retinæ. This explanation, however, even supposing the fact to be as stated, would be far from affording the solution of the problem; and it would be entirely inapplicable to that very important series of phenomena to be next described, which show how large an amount of information we derive, not from the *repetition*, but from the *difference*, of the sensory impressions made by the same object upon our two retinæ; and which indicate that here, as in the case of erect vision, the *mental interpretation* of the sensory impressions is a process altogether removed from the simple affection of the consciousness by those impressions, and is not to be accounted for by any structural arrangements of the Sensorial apparatus. One condition of Single Vision, however, seems to be this, that the two images of the object should be formed on parts of the two retinæ which are *accustomed* to act in concert; and *habit* appears to be the chief means by which this conformity is produced (§ 800). There can be no doubt, however, that double images are continually being conveyed to the Sensorium; but that, from their want of force and distinctness, and from the attention being fixed on something else, we do not take cognizance of them. This may be shown by a very simple experiment. If two fingers be held up before the eyes, one in front of the other, and vision be directed to the more distant, so that it is seen singly, the nearer will appear double; while, if the nearer one be regarded more particularly, so as to appear single, the more distant will be seen double. A little consideration will show, therefore, that our minds must be thus continually affected with sensations, which cannot be united into the idea of a single image; since, whenever we direct the axes of our eyes towards any object, everything else will be represented to us as double; but we do not ordinarily perceive this, from our minds being fixed upon a clear and distinct image, and disregarding, therefore, the vague undefined images formed by objects not in the visual focus. Of this it is very easy to satisfy one's self.—This

experiment, moreover, makes it evident that double vision cannot result from *want of symmetry* in the position of the images upon the retina, to which some have attributed it; for it answers equally well, if the line of the two fingers be precisely in front of the nose, so that the inclination of both eyes towards either object is equal; the position of the images of the second object must then be at the same distance on either side from the central line of the retina, and yet they are represented to the mind as double. Hence, too, it seems clear that singleness of vision in an object that is *looked at*, is also dependent in part upon the *convergence of the optic axes* on that object (§ 752); and that this is the case appears further from a curious experiment devised by Prof. Wheatstone, in which two similar objects are made to seem as one, when they are placed in the line of convergence. This is accomplished by looking through two tubes, placed before the right and left eyes respectively, at two similar objects of any description, placed near the farther extremities of the tubes; if, now, these objects be slightly approximated, so that the axes of the tubes (still directed towards them) meet in a point beyond, the mind is impressed with the image of only a single object, and this appears to be removed back to the point of convergence.

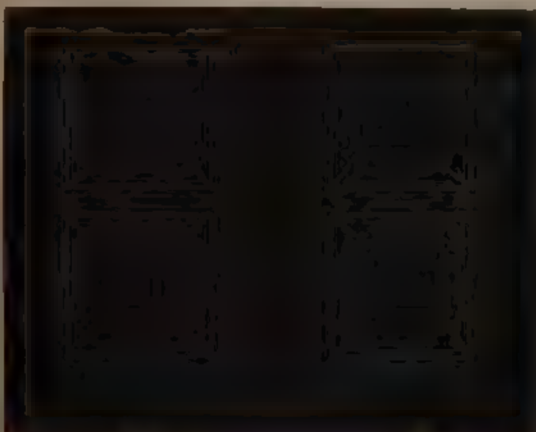
761. On the mode in which our notion of the *solid forms* and *relative projection* of objects is acquired, great light has been thrown by the interesting experiments of Prof. Wheatstone.* It seems perfectly evident, both from reason and experience, that the flat picture upon the retina, which is the immediate source of our sensation, could not itself convey to our minds any notion, but that of a corresponding plane surface. In fact, any notion of *solidity*, which might be formed by a person who had never had the use of more than one eye, would entirely depend upon the combination of his visual and tactile sensations. This view is fully confirmed by the case already referred to (§ 758), as recorded by Cheselden. The first visual idea entertained by the youth was, that the objects around him formed a flat surface, which touched his eyes, as they had previously been in contact with his hands; and after this notion had been corrected, through the education of his sight by his touch, he fell into the converse error of supposing that a picture, which was shown to him, was the object itself represented in relief on a small scale.—But where both eyes are employed, it has been ascertained by Prof. Wheatstone, that they concur in exciting the perception of solidity or projection, which arises from the *mental* combination of the two *dissimilar* pictures formed upon the two retinæ. It is easily shown, that any *near* object is seen in two different modes by the two eyes. Thus let the reader hold-up a thin book, in such a manner that its back shall be exactly in front of his nose, and at a moderate distance from it, he will observe, by closing first one eye and then the other, that his perspective view of it (or the manner in which he would represent it on a plane surface) is very different, according to the eye with which he sees it. With the right eye he will see its right side, very much fore-shortened; with the left, he will gain a corresponding view of the left side; and the apparent angles, and the lengths of the different lines, will be found to be very different in the two views. On looking at either of these views singly, no other notion

* "Philosophical Transactions," 1838 and 1852.

receding surface, the exact counterpart of that from which the drawings were made.* The solid form is forcibly impressed on the mind, even when outlines only are given, especially if these be delineations of simple geometrical figures, easily suggested to the mind; and it may be readily shown that the very same outlines will suggest different conceptions, according to the mode in which they are placed. Thus in Fig. 103, the

FIG. 103.

A B



C D

upper pair of figures A, B, when combined in the Stereoscope, excite the idea of a *projecting* truncated pyramid, with the small square *in the centre*, and the four sides sloping equally *away from* it; whilst the lower pair of figures, C, D, which are the same as the upper, but transferred to the opposite sides, no less vividly bring before the mind the visual conception of a *receding* pyramid, still with the small square in the centre, and the four sides sloping equally *towards* it.—Prof. Wheatstone has further shown, by means of the Stereoscope, that similar images, differing to a certain extent in magnitude, when presented to the corresponding parts of the two retinæ, give rise to the perception of a single object, intermediate in size between the two monocular pictures. Were it not for this, objects would appear single, only when at an equal distance from both eyes, so that their pictures upon the retina are of the same size; which will only happen, when they are directly in front of the median line of the face. Again, if pictures of dissimilar objects be simultaneously presented to the two eyes, the consequence will be similar to that which is experienced, when the rays come to the eye through two differently coloured media; the two images do not coalesce, nor do they appear permanently superposed one upon the other; but at one time one image pre-

* The most striking effect is produced by two Photographic pictures, taken at the same time by two cameras, so placed that their axes shall form the same angle with each other as that which the axes of the two eyes would form when looking at the same object. This adaptation, though the credit has been assumed by others, was originally devised by Prof. Wheatstone.

dominates to the exclusion of the other, and then the other is seen alone; and it is only at the moment of change, that the two seem to be intermingled. It does not appear to be in the power of the Will, Prof. Wheatstone remarks, to determine the appearance of either; but if one picture be more illuminated than the other, it will be seen during a larger portion of the time. If, however, the differences in the two pictures be such that the Mind can reconcile them, an *intermediate* conception is formed; thus if two photographic portraits be taken at the proper angle for the Stereoscope, not simultaneously but consecutively, and the 'sitter' alter his expression in the interval, so that one of the portraits represents him with a smile, and the other with a frown, the Stereoscopic image will present an intermediate expression of placidity. —Many other curious experiments with this simple instrument are related by Prof. Wheatstone; and they all go to confirm the general conclusion, that the combination of the dissimilar images furnished by the two eyes is *a mental act*, the resultant of which, in the case of all objects that are near enough to be seen in different perspective with the two eyes, is a mental image (referred to the visual sense) possessing the attributes of solidity and projection. In regard to distant objects, however, the difference in the images formed by the two eyes is so slight, that it cannot aid in the determination; and hence it is, that whilst we have no difficulty in distinguishing a picture, however well painted, from a solid object, when placed near our eyes (since the idea which might be suggested by the image formed on one eye, will then be corrected by the other),* we are very liable to be misled by a delineation, in which the perspective, light and shade, &c., are faithfully depicted, if we are placed at a distance from it, and are prevented from perceiving that it is *but* a picture.† In this case, however, a slight movement of the head is sufficient to undeceive us; since by this movement a great change would be occasioned in the perspective view of the object, supposing it to possess an uneven surface; whilst it scarcely affects the image formed by a picture. In the same manner, a person who only possesses one eye, may obtain, by a slight motion of his head, the same idea of the form of a body, which another would acquire by the simultaneous use of his two eyes.

763. Our appreciation of the relative Distances of *near* objects, seems to be derived in like manner from the mental combination of the perceptions derived from the dissimilar pictures upon the two retinæ, assisted by the sensations derived from the muscles of the eyeballs, which are put in action to bring the optic axes into the requisite convergence. How much our right estimation of the relative distances of objects not too far removed from the eye, depends upon the joint use of *both eyes*, is made

* It is a remarkable illustration of this principle, that a photographic representation of a landscape, building, &c., when viewed with *one eye* at a moderate distance, frequently brings the real scene far more forcibly before the mental vision than when it is looked at with both eyes; since, in the latter case, the mind cannot avoid perceiving the flatness of its surface; whilst, in the former, the perspective, and the distribution of the lights and shadows, are free to suggest to the mind the relative distances and projections of the several parts.

† This delusion has been extremely complete, in some of those who have seen the panoramic view of London in the Colosseum. A lively and interesting account of it is given in the Journal of the Parsee Shipbuilders, who visited England some years ago.

evident by the fact, that, if we close one eye, we find ourselves unable to execute with certainty many actions (such as threading a needle, or snuffing a candle) which require its guidance. In proportion as the object is approximated to the eyes, slight differences of distance produce marked differences in the degree of convergence, and these are readily appreciated so as to afford the means of very nice discrimination; whilst, on the other hand, in proportion as they are removed further and further, as the optic axes approach parallelism, and the power of appreciating differences of distance is lost. It is the usual opinion that the muscular sensation which accompanies the inclination of the optic axes, *immediately suggests* the notion of the *distance* of an object; and that our appreciation of its *size* depends upon a secondary *interpretation* of the magnitude of its picture on the retina, on the basis of this notion. But it would appear from the experiments of Prof. Wheatstone, that the reverse is the case; the sensation of convergence assisting in the first instance to determine the size, and the appreciation of distance being a secondary judgment based on this foundation (§ 766).—The power of estimating distance from the foregoing data, however, is obviously, in Man, not an intuitive but an acquired endowment; for it is evident to any observer, that infants, or older persons who have but recently acquired sight, form very imperfect ideas respecting the distance of objects; their attempts to grasp bodies which attract their attention, being for a long time unsuccessful, so that they only gradually learn to measure distances by the sight, through the medium of the touch. And it seems to follow from this, that even the notion of 'projection,' which we seem necessarily to form when looking at a solid object within a moderate distance, or at a properly-adjusted pair of Stereoscopic pictures, is not derived from an original intuition, but is the result of the association of our visual with our tactile experience, very early in life, so as to constitute a 'secondary intuition' on which all our subsequent appreciation of projection is based.

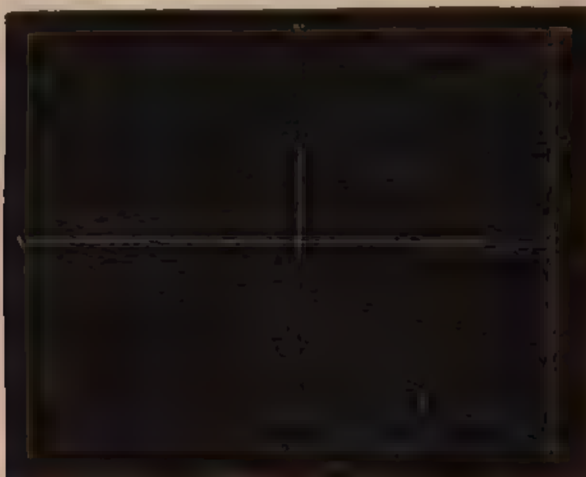
764. In regard to *remote* objects, our judgment of Distance is chiefly founded upon their apparent size, if their actual size be known to us; but, if this be not the case, and if we are so situated that we cannot judge of the intervening space, we principally form our estimate from that effect of different degrees of remoteness upon the distinctness of their colour and outline, which is known to Artists as 'aerial perspective.' Hence this estimate is liable to be greatly affected by varying states of the atmosphere, as is particularly known to every one who has visited warmer climates; where the extreme clearness of the air sometimes brings into apparently-near proximity a hill that rises some miles beyond a neighbouring ridge (the intervening space being hidden, so as not to afford any datum for the estimate of the distance of the remote hill), whilst a slight haziness carries its apparent distance to three or four times the reality.

765. Our estimate of the Size of a *remote* object is partly dependent upon the *visual angle* under which we see it, and partly upon our estimate of its *distance*.* The 'visual angle,' formed by imaginary lines drawn

* When objects are so remote that we have no means of even approximately estimating their *distance*, we have no measure whatever of their *size*. Thus, the Sun and the Moon are of nearly the same apparent size to us, though one is about four hundred times the distance of the other; and we may cover either disc with a sixpence held near the eye, so

from the eye, (Fig. 104, A) to the extreme points B, C, of the object, is the measure of the dimension of its image upon the retina; and it is

Fig. 104.



obvious that, if two objects, B C, D E, the former being twice the length of the latter, be placed at the same distance, the visual angle B A C being twice as great as the angle D A E, the image of B C upon the retina will be twice as long as that of D E, and the mind will estimate their relative sizes accordingly. But if the distance of the object D E from the eye be diminished to one-half, so that it is brought into the position F G, its visual angle, and consequently the size of its image on the retina, will now be equal to that of B C; and the estimate we form of the relative sizes of the two, will entirely depend upon the idea we entertain of their relative distances. Hence any circumstance which modifies that idea, produces a corresponding difference in our estimate of their size; so that the apparent size of an object, seen under the same visual angle, may be estimated as larger or smaller than the reality, according as we suppose it to be more or less distant than it really is. Of this we have a familiar instance in the fact, that if we meet a child whilst we are walking across a common in a fog (the flatness of the ground not giving us much power of estimating the intervening space), it appears to have the stature of a man, and a man seems like a giant; for the indistinctness of outline causes the mind to conceive of the figures as at a greater distance than they really are, and their apparent dimensions are augmented in like proportion. For if the object F G (Fig. 104) be *mentally carried-back* to the distance of D E, being still seen under the visual angle F A G (or B A C), it will appear to possess the length B C instead of D E. On the other hand, if the object B C were to be *mentally brought forwards* into the

as to be seen under the same visual angle, but we do not possess the least power of estimating the actual sizes of these objects, save by a calculation based on a knowledge of their relative distances.

position K L, its apparent size being still determined by its visual angle, it will seem to be reduced to the length F G.

766. That our estimate of the Size of *near* objects, however, depends upon a more direct process, seems to be a necessary inference from the following very ingenious experiments, made by Prof. Wheatstone with a modification of his Mirror-Stereoscope, devised for separately testing the influence of the two conditions,—namely, the magnitude of the retinal picture, and the degree of convergence of the optic axes,—which are ordinarily in action together. When an object is moved nearer-to or farther-from the eye, its *perceived* or estimated magnitude undergoes no change. But if two pictures, placed in the mirror-stereoscope, be made to move to and from the mirrors, in such a manner as to vary their *distances* from these (and therefore from the eyes), without altering the angle of convergence, their perceived magnitudes are augmented and reduced, in precise proportion to the increased and diminished sizes of the retinal pictures. Conversely, if the two pictures be made so to change their places in regard to the mirrors (by moving in a horizontal circle, of which the middle-point between the mirrors is the centre), that the *angle of convergence* is increased or diminished, as it would be if the object were brought nearer to the eyes or removed farther from them, the perceived magnitude of the pictures is altered in an inverse manner; being reduced when the angle of convergence is increased, and increased when the inclination of the optic axes is lessened so as to approach parallelism. Thus it appears that the absence of alteration in the perceived magnitude of an object as ordinarily seen at varying distances, is the result of the inverse action of these two kinds of suggestion; for the enlargement of the retinal picture, when acting alone, occasions an increase in the perceived magnitude, whilst an increase of convergence, taking-place by itself, diminishes the perceived magnitude; and thus, as these alterations occur simultaneously when an object is approximated to the eye, its dimensions seem to undergo no change; as will also be the case, when, by the removal of the object to a greater distance, these conditions are again made to vary simultaneously, though in a contrary direction.—It may further be remarked, that in the first of the foregoing experiments, the picture whose perceived magnitude is undergoing enlargement or diminution in consequence of the alteration of its retinal magnitude, seems evidently to be approaching and receding; yet if we fix our attention on it when it is stationary, at any instant, it appears to be at the same distance at one time as at another, the effect being very much like that of the Phantasmagoria, in which the alteration in the size of the images on the screen suggests the notion of their approach or recession, although we are quite sensible that the distance of the screen from our eyes remains constantly the same. In the second experiment, on the other hand, the picture whose perceived magnitude is undergoing diminution or enlargement in consequence of increase or lessening of the angle of convergence, does not appear either to approach or recede, and yet, when attentively regarded in different fixed positions, it is felt to be at different distances. Hence, as Prof. Wheatstone observes, convergence of the optic axes suggests fixed distance to the mind, whilst variations of retinal magnitude suggest change of distance; and, however paradoxical it may seem, "we may perceive an object approach or recede, without appearing to change

its distance, and an object to be at a different distance without appearing to approach or recede."*—A like alteration in apparent size is produced, when two pairs of figures (such as those given in Fig. 103), the effect of one of which is to suggest a *projecting*, and that of the other a *receding* form, are viewed at the same time in the ordinary Stereoscope. For it will be observed that the relative size of the parts which appear to project is reduced, whilst that of the apparently-receding parts is augmented; as is particularly the case with the square truncated end of the pyramid, which is estimated by most persons as from one-third to one-half larger in each of its dimensions in the receding, than it is in the projecting pyramid, notwithstanding that the actual sizes of the squares in the two sets of figures are precisely the same. For supposing H I (Fig. 104) to represent the real side of one of the small squares, which becomes the truncated end of the pyramid, when this is brought-forward by the mind into the position K L, as the truncated top of a projecting pyramid, being seen under the visual angle H A I, its apparent size is reduced to F G; whilst, on the other hand, the very same square, carried-back by the mind to the distance D E, as when it forms the truncated end of the receding pyramid, is mentally enlarged to the dimensions B C, the visual angle B A C being the same as H A I.

767. The large share which the Mind has, in the interpretation of even such visual impressions as seem to us *necessarily* to induce particular perceptions, is further shown by a very remarkable class of phenomena, termed by Prof. Wheatstone (their discoverer) *Conversions of Relief*. The simplest example of this class is presented by the alteration in the visual product of the same Stereoscopic pictures, when their positions are transposed. Thus the very same diagrams, which, as placed in the upper part of Fig. 103, bring before the mind's eye the conception of a projecting pyramid, when changed to the position which they occupy in the lower part of that figure, call-up the image of a receding pyramid. And a corresponding effect is produced by the reversal of any other pair of Stereoscopic pictures; all that should project being made to recede, all that should recede being made to project, *provided the converse has any meaning* which the Mind can readily appreciate. But the same effects may be produced, if the objects themselves are looked-at by an instrument devised by Prof. Wheatstone, and termed by him the *Pseudoscope*; the optical effect of which is, to reverse the ordinary visual relations between the near and distant parts of an object; the two conditions described in the preceding paragraph being combined inversely, so that, as an object or part of an object is nearer the eye, its larger picture on the retina is accompanied by a diminished convergence of the optic axes. When the impression of a seal is looked at with this instrument, it is converted into the representation of the seal itself; or, if the seal be looked-at, it presents the figure raised in relief, as in its ordinary impression. So, the inside of a cup or basin appears as a solid convex body; whilst the outside appears depressed and concave. A bust

* See "Philos. Transact.," 1852, pp. 2-5. The Author thinks it well to add that he has himself verified the above very curious results, which are scarcely less valuable contributions to the Physiology of Binocular vision, than those earlier attained by the same eminent experimentalist.

regarded in front becomes a deep hollow mask, whilst the interior of the cast of a face presents the appearance of the face in its ordinary relief. A china vase, ornamented with coloured flowers in relief, seems like a vertical section of the interior of such a vase, with hollow impressions of the flowers. The base of a brain seems concave, like the interior of the base of the skull which is its reflex; and the latter seems convex and projecting, like the base of the brain.—These and similar appearances are not always immediately perceived, and some present themselves much more readily than others. Those converse forms which we are *accustomed* habitually to see, or which have a *meaning* that the mind can easily apprehend, are those which are most readily perceived. Thus, the illusion which may be produced with a bust or with the cast of a face, is not easily obtainable even by a lengthened pseudoscopic contemplation of the *real* face, which we can scarcely conceive-of as thus 'turned inside out.' Another very interesting fact is, that those to whom the illusion does not at first present itself, usually find it *suddenly* come upon them after a little time, especially if they should have directed their minds to the imaginary conception of the object under its changed aspect. And, further, when the conversion has taken place, the natural aspect of the object continues to intrude itself, sometimes suddenly, sometimes gradually, and for a longer or shorter interval, when the converse will again succeed it. This is due to the involuntary alternation of the attention, between the conception suggested to the mind by the visual impressions derived from both eyes, and that which is derived from either eye singly (§ 762), the latter, moreover, harmonising-with and being strengthened-by our recollection of the object as we have seen it before, or (if it be new to us) by our notion of its natural appearance.

768. The *persistence*, during a certain interval, *of impressions made upon the retina*, gives rise to a number of curious visual phenomena, which can be here only briefly adverted-to. The prolongation of the impression will be governed, in part, by its previous duration; thus, when we rapidly move an ignited point through a circle, the impression itself is momentary, and remains but for a short period; whilst, if we have been for some time looking at a window, and then close our eyes, the impression of the dark bars traversing the illuminated space is preserved for several seconds. One of the results of this persistence is the combination, into a single image, of two or more objects presented to the eye in successive movements; but these must be of a kind which can be united, otherwise a confused picture is produced. Thus in a little toy, called the Thaumatrope, which was introduced some years ago, the two objects were painted on the opposite sides of a card,—a bird, for instance, on one, and a cage on the other; and, when the card was made (by twisting a pair of strings) to revolve about one of its diameters, in such a manner as to be alternately presenting the two sides to the eye at minute intervals, the two pictures were blended, the bird being seen in the cage. A far more curious illusion, however, was that first brought into notice by Prof. Faraday; who showed that, if two toothed wheels, placed one behind the other, be made to revolve with equal velocity, a stationary spectrum will be seen; whilst if one be made to revolve more rapidly than the other, or the number of teeth

be different, the spectrum also will revolve. The same takes-place when a single wheel is made to revolve before a mirror, the wheel and its image answering the purpose of the two wheels in the former case. On this principle, a number of very ingenious toys have been constructed; in some of these, the same figure or object is seen in a variety of positions; and the successive impressions, passing rapidly before the eye, give-rise by their combination to the idea, that the object is itself moving through these positions.*—It is interesting to remark, moreover, that when the eye has been for some time contemplating an object in motion, and is then directed towards stationary objects, *these* appear for a short time to have a like movement. Any rail-road traveller may try this simple experiment, by first looking at the hedges, &c. which he is rapidly passing, and then at some part of the interior of the carriage itself, especially one which presents a series of parallel lines. But when the impression of movement has been of longer duration, its effects are less transient; thus, a person who has been for some time on board ship, sees the floors, walls, and ceilings of his apartments on shore in a state of continual up-and-down motion, even for some days after he has landed. This would seem to be rather a *sensorial* than a *retinal* phenomenon.

769. When the Retina has been exposed for some time to a strong impression of some particular kind, it seems less susceptible of feebler impressions of the same kind. Thus, if we look at any brightly luminous object, and then turn our eyes on a sheet of white paper, we shall perceive a dark spot upon it; the portion of the retina which had been affected by the bright image, not being able to receive an impression from the fainter rays reflected by the paper. The dark spectrum does not at once disappear, but assumes different colours in succession,—these being expressions of the states through which the retina is passing, in its transition to the natural condition. If the eye has received a strong impression from a *coloured* object, the spectrum exhibits the *complementary* colour;† thus, if the eye be fixed for any length of time upon a bright red spot on a white ground, and be then suddenly turned so as to rest upon the white surface, we see a spectrum of a green colour.—The same explanation applies to the curious phenomenon of 'coloured shadows.' It may not unfrequently be observed at sunset, that, when the light of the sun acquires a bright orange colour from the clouds through which it passes, the shadows cast by it have a blue tint. Again, in a room with red curtains, the light which passes

* A very beautiful 'philosophical toy' was shown to the Author some years since, by its inventor, Mr. Roberts, the celebrated machinist of Manchester; consisting in an apparatus by which it was made possible to read words printed on a card, although the card itself was made to revolve on its axis even 40,000 times in a minute. The principle of its construction was simply this, that the eye caught a succession of glimpses of the card, through a narrow slit before which a disk with a single corresponding perforation was made to revolve; the rate of movement of this disk being so adjusted to that of the card, that whenever the eye caught sight of the latter, it was *momentarily* in the same position, so that, by the succession of transient impressions thus made upon the retina, the words printed on the card could be distinctly read.

† By the 'complementary' colour is meant that which would be required to make white or colourless light, when mixed with the original. As red, blue, and yellow are the primary or elementary colours, red is the complement of green (which is composed of yellow and blue), blue is the complement of orange (red and yellow); and yellow of purple (red and blue), and *vice versâ* in all instances.

through these produces green shadows. In both instances, a strong impression of one colour is made on the general surface of the retina, and at any particular spots, therefore, at which the light is colourless but very faint, that colour is not perceived, its complement only being visible. The correctness of this explanation is proved by the fact, that, if the shadow be viewed through a tube, in such a manner that the coloured ground is excluded, it seems like an ordinary shadow. It is not unlikely that, as Muller suggests, the predominant action of one colour on the retina disturbs (as it were) the equilibrium of its condition, and excites in it a tendency to the development of a state corresponding to that which is produced by the impression of the complementary colour; for the latter is perceived, as he remarks, even where it does not exist; as when the eye, after receiving a strong impression from a coloured spot, and being directed upon a completely dark surface or into a dark cavity, still perceives the spectrum. This change, indeed, extends beyond the spot on which the impression is made (§ 771), for, as is well known to Artists, the sensory impression produced by any colour is greatly affected by neighbouring hues. Thus, if four strips of coloured paper, or any other fabric, A, B, C, D,—two of them, A, B, of one colour (*e. g.* red), and the other two, C, D, of some different colour (*e. g.* blue),—be laid side-by-side at intervals of about half an inch, the hues of the two central strips B, C, will be decidedly modified by each other's proximity, each approximating to the hue of the complementary colour of the other; so that instead of

A	B	C	D
red	red	blue	blue

we shall see

A	B	C	D
red	orange-red	greenish-blue	blue.

770. Upon the properties of the Eye in regard to Colour, are founded the laws of harmonious colouring, which have an obvious analogy with those of musical harmony. All complementary colours have an agreeable effect, when judiciously disposed in combination; and all bright colours, which are not complementary, have a disagreeable effect, if they are predominant: this is especially the case in regard to the simple colours, strong combinations of any two of which, without any colour that is complementary to either of them, are extremely offensive. Painters who are ignorant of these laws, introduce a large quantity of dull grey into their pictures, in order to diminish the glaring effects which they would otherwise produce; but this benefit is obtained by a sacrifice of the vividness and force, which may be secured in combination with the richest harmony, by a proper attention to physiological principles.*—Some persons whose visual powers are excellent in every other respect, are more or less deficient in the power of discriminating *colours.* This defect (which is now commonly known as 'Daltonism,' from the name of the distinguished philosopher who was

* This subject has been most carefully and elaborately investigated by M. Chevreul; whose recent Treatise on Colours has almost exhausted the enquiry into the mode in which the Visual sense of Man is affected by them.

himself the subject of it) may be so complete, that nothing can be perceived save different degrees of light and shadow; more commonly, however, it exists only with regard to particular colours especially such as have a complementary relation to one another, so that persons thus affected are unable (*e.g.*) to distinguish ripe cherries among the leaves of the tree, save by their form; whilst in some individuals it does no more than confuse colours that are nearly related, such as green and blue, especially when they are seen by artificial light. Whether its seat be in the nervous apparatus of the Eye, or in the Sensorium, cannot be positively determined; but the latter seems the most probable supposition.*

771. The impressions made by luminous objects upon the Retina, are not precisely confined to the spots upon which their rays impinge, but extend themselves to a greater or less distance around; which phenomenon has been termed *irradiation*. Thus if we make a circular white spot upon a black ground, and a black spot of precisely the same dimensions upon a white ground, the former will seem to be considerably larger than the latter; apparently because the excitation of the retina by the luminous impression tends to spread itself in each case over the adjacent non-excited space. Hence it is that we are able to distinguish any small magnitudes, such as letters or the lines of a diagram, at a much greater distance, when they are marked in white on a black ground, than when inscribed in black upon a white ground. Another curious case of the same kind has been noticed by Sir D. Brewster.† "If we shut one eye, and direct the other to any fixed point, such as the head of a pin, we shall see indistinctly all other objects within the sphere of vision. Let one of these objects thus indistinctly seen, be a strip of white paper or a pen lying on a green cloth. Then, after a short time, the strip of paper, or the pen, will disappear altogether, as if it were entirely removed; the impression of the green cloth upon the surrounding parts of the retina, extending over that part of it which the image of the pen occupied. In a short time the vanished image will re-appear, and again vanish: when both eyes are open, the very same effect takes place, but not so readily as with one eye. If the object seen indistinctly is a black stripe on a white ground, it will vanish in a similar manner. When the object seen obliquely is luminous, such as a candle, it will never vanish entirely, unless its light is much weakened by being placed at a great distance; but it swells and contracts, and is encircled by a nebulous halo."

772. The power of receiving and transmitting visual impressions is by no means uniformly diffused over the entire Retina. In the whole field of vision which at any time lies before us, we only see with perfect distinctness that part to which the axes of our eyes are directed, and of which the image, therefore, is formed upon the 'yellow spot' (§ 755). Nevertheless we have a sufficiently distinct perception of the remainder of the field, to enable us to judge of the relations of the objects which are distinctly seen, to those which surround them; and the mobility of our eyes enables us, under the guidance of our visual sense (§ 546), to direct the most sensitive spot of the retina to every part of the field in

* See especially the Memoir of Prof. Seebeck, in "Poggendorf's Annalen," band xlii. (1837); and that of Prof. Wartmann in "Taylor's Scientific Memoirs," vol. iv. p. 156.

† "Treatise on Optics," in Lardner's Cyclopædia, p. 296.

succession, not only without effort, but even almost without the consciousness that we are doing so.—Generally speaking, the indistinctness of vision for objects seen out of the axis of the eye, increases with the distance of their images from the central point; or, in other words, the impressibility of the several parts of the retina diminishes, according to their distance from the 'yellow spot.' But there is one part of the retinal surface, namely, the seat of entrance of the Optic Nerve, which is remarkable for its imperfect receptivity; as is shown by the following experiment. Let two black spots be made upon a piece of paper, about four or five inches apart; then let the left eye be closed, and the right eye be strongly fixed upon the left hand spot; if the paper be then moved backwards and forwards, so as to change its distance from the eye, a point will be found at which the right-hand spot is no longer visible though it is clearly seen when the paper is brought nearer or removed further. In this position of the eye and the object, the rays from the right-hand spot cross to the nasal side of the globe, and fall upon the point of the retina which has just been mentioned. If the same experiment be tried with candles, the image will not entirely disappear, but will become a cloudy mass of light. It is not correct to say, as is sometimes done, that the retina is not impressible by light at this point; since, if such were the case, we should see a dark spot in our field of view whenever we use only one eye, which is not the case. The fact seems rather to be, that this portion of the retina is very inferior to the surrounding parts in its receptivity for luminous impressions; whilst, on the other hand, there is an unusual tendency to the extension of *their* condition to it by 'irradiation' (§ 771); so that, in the experiment just described, if the black spots be made upon a coloured ground, this colour will take the place of the spot which disappears.

773. The impression made by rays of light upon the Retina, may be to a certain extent imitated by other physical agencies (§ 731), which thus give rise to various *subjective* visual phenomena. Advantage has recently been taken by Dr. Serre,* of the power of mechanical pressure to produce luminous spectra, for the investigation of the 'law of visual direction' (§ 759); and the results which he has obtained are of very great interest. When any part of the globe of the eye is compressed (the experimenter being in a completely-darkened room), a luminous figure is seen to be projected in the direction opposite to the spot pressed upon. Its form varies according to that of the compressing body, and to the degree in which the retina is affected by it. Thus if the pressure be made by the point of the finger, or by any other circular surface, upon a part of the globe over the interior of which the retina is continuous, the spectrum, or *phosphène* (as it is termed by Dr. Serre), is also circular; if the compressing body, on the other hand, be square at its extremity, the 'phosphène' is also square; and if it be triangular, the 'phosphène' is triangular too. But if the pressure be made near the anterior edge of the retina (which is what most commonly happens, unless the most favourable situation be designedly chosen), the figure of the 'phosphène' is incomplete; and the degree of its deficiency cor-

* See his "Essai sur les Phosphènes," Paris, 1853.

responds with the proportion of the area of compression that does not lie-over the retinal expansion. Hence there can be no hesitation in regarding the production of this spectrum as the immediate result of the affection of the sensorium by the pressure on the retina; and as it seems to our perceptive consciousness to have a distinct objective existence, and as its position bears a constant and definite relation to that of the portion of the retina on which the impression is made, it seems obvious that any such affection of the retina not only intuitively suggests to our minds the notion of an external objective cause of the impression, but also indicates to our consciousness the *direction* of the object.—But further, besides the principal 'phosphène,' another, of smaller dimensions, is usually to be seen, in a direction nearly the same as that on which the pressure is made; this is the result of the transmission of the pressure to the *opposite* side of the globe, by an alteration of its figure and of the position of its contents, which corresponds to the fracture of the skull by *contre-coup*. The form of this smaller or secondary 'phosphène' is not affected by the cause which sometimes renders the larger or primary spectrum incomplete; since, as we cannot anywhere apply pressure to the living Human eye, save on some part of its anterior hemisphere, the 'contre-coup' will always take-place at the opposite spot in the posterior hemisphere, over which the retina is continuous, save at the entrance of the optic nerve. By an extensive series of observations upon the relation of the positions of the primary and secondary 'phosphènes,' both to each other and to the seat of compression, Dr. Serre has deduced the important conclusion, that the lines joining the imaginary spectra and the spots of the retina from whose affection they respectively proceed, pass through a common 'centre of direction,' whose position is in the middle of the crystalline lens. And hence it seems to be a legitimate conclusion, that our sense of the relative directions of external objects is derived from a kind of mental projection of each point of the retinal image, in the line which joins it to this 'centre of direction.'

774. Another very curious *subjective* phenomenon of Vision, is the representation which, under particular circumstances, we may mentally obtain of the retina itself; as in the following experiment, first devised by Purkinje, and known by his name. "If in a room otherwise dark, a lighted candle be moved to and fro, or in a circle, at a distance of six inches before the eyes, we perceive, after a short time, a dark arborescent figure ramifying over the whole field of vision; this appearance is produced by the vasa centralia distributed over the retina, or by the parts of the retina covered by those vessels. There are, properly speaking, two arborescent figures, the trunks of which are not coincident, but on the contrary arise in the right and left divisions of the field, and immediately take opposite directions. One trunk belongs to each eye, but their branches intersect each other in the common field of vision. The explanation of this phenomenon is as follows:—By the movement of the candle to and fro, the light is made to act on the whole extent of the retina, and all the parts of the membrane which are not immediately covered by the vasa centralia are feebly illuminated; those parts, on the contrary, which are covered with those vessels, cannot be acted-on by the light, and are perceived, therefore, as dark arborescent figures. These

figures appear to lie before the eye, and to be suspended in the field of vision."* We have thus another demonstration of the fact, that, in ordinary Vision, the immediate object of our sensation is a certain condition of the retina, which is excited by the formation of a luminous image.

775. The Visual power is susceptible of extraordinary improvement, through the habitual direction of our *attention* to the effects produced upon our consciousness by the impressions transmitted to the Sensorium from the Eye; and this improvement may take place, either in regard to the quickness and readiness with which objects generally are perceived, or in the faculty of discriminating the slightest differences in form, shade, colour, &c., or of discerning bodies of extreme minuteness. In regard to all these points it may be noticed, that the habit of attention to any particular class of objects, sharpens the discriminating power for that class alone; and that it is usually rather the mental than the corporeal vision which undergoes improvement. Thus the Seaman who makes-out the 'loom of the land' where the landsman can discern nothing but an indefinite haze above the horizon, or who can distinguish the size, rig, and course of a vessel, which the landsman can but just see as a formless speck, does so in virtue of the aptitude of his mind for receiving suggestions from minute indications, such as pass unnoticed by those who have not been accustomed to form their ideas upon the same kind of experiences. And the Microscopist, who is constantly on the outlook for the various forms of organic structure with which his mind is familiar, discerns these without difficulty or hesitation, where an ordinary observer sees nothing but a confused jumble of tissue.—It is interesting to observe that the power of descrying objects at vast distances, appears to be hereditarily possessed by two races of men, the Mongols of Northern Asia, and the Hottentots of Southern Africa, both of which habitually dwell on vast plains, that seem to stretch without limit in every direction. It seems probable that this power was in the first instance acquired by habit in each case; and that, as frequently happens with acquired peculiarities which are kept-up by constant use in successive generations,† it has become fixedly hereditary.

6.—*Sense of Hearing.*

776. In the Ear, as in the Eye, the impressions made upon the sensory nerve are not at once produced by the body which originates the sensation; but they are propagated to it, through a medium capable of transmitting them. We obviously take cognisance by the mind, therefore, not of the sonorous object, but of the condition of the auditory nerve; and all the ideas we form of sounds, as to their nature, intensity, direction, &c., must be based upon the changes which they produce in it. The complex contrivances which we meet-with in the organ of Hearing among higher animals, are evidently intended to give them greater power of discriminating sounds, than is possessed by the lower tribes; in which last it is reduced to a form so simple, that it may be questioned whether they can be said to possess an organ of *hearing*, if by this term we imply anything more than the mere consciousness of sonorous vibrations.—There

* Muller's "Elements of Physiology" (Baly's Translation), p. 1163.
† See "Princ. of Comp. Physiol.," § 620

is a considerable difference, however, between the Eye and the Ear, in regard to the special purposes for which they are respectively adapted. In the former, we have seen that the whole object of the instrument is to direct the rays of light received by it, in such a manner, as to occasion them to fall upon the expansion of the optic nerve in similar relative positions, and with corresponding proportional intensities, to those which they possessed when issuing from the object. We have no reason to believe anything of this kind to be the purpose of the Ear; indeed it would be inconsistent with the laws of the propagation of sound. Sonorous vibrations having the most various directions, and the most unequal rates of succession, are transmitted by all media without modification, however numerous their lines of intersection; and wherever these undulations fall upon the auditory nerve, they must cause the sensation of corresponding sounds. Still it is probable that some portions of the complex organ of hearing, in Man and in the higher animals, are more adapted than others to receive impressions of a particular character; and that thus we may be especially informed of the direction of a sound by one part of the organ, of its musical tone by another, and of some other of its qualities by a third.

777. The essential part of an Organ of Hearing is obviously a nerve, endowed with the peculiar property of receiving sonorous undulations, and of transmitting their effects to the Sensorium. This nerve is spread out over the surface of a delicate membrane which lines the Vestibule and its prolongations; and this membrane encloses a fluid, which is the medium whereby the sonorous vibrations received through the external ear, are communicated to the nerve. We learn from an examination of the comparative structure of the auditory apparatus in the lower animals, and from the study of its development in the higher, that the part which, being most constantly present and being also the earliest in its development, may be considered as the most essential, is the simple *Vestibular* cavity, which exists where there are no vestiges either of Semicircular Canals, of Cochlea, or of Tympanic apparatus. Such a condition presents itself in some of the higher Invertebrata and in the lowest Fishes, but as we ascend the Vertebrated series, we find the semicircular canals growing out (as it were) of the Vestibule in Fishes, a tympanic apparatus superadded in Reptiles, and a Cochlea first acquiring a more than rudimentary development in the class of Birds, although only presenting in Mammalia that characteristic form from which it derives its name.* Of the mode in which the ultimate subdivisions of the Auditory nerve are distributed upon the lining membrane of the labyrinth, it does not yet seem possible to give a certain account, for although Wagner and others have represented them as terminating in free loops, yet more careful observation has rendered this doubtful, and the general analogy between the simpler forms of the auditory and of the visual apparatus, as well as the close correspondence which exists between them in the history of their development (the organ of hearing, like the eye, being budded-off from its sensory ganglion, § 911), seem to indicate that the peripheral expansion of the auditory nerve might be expected to have a structure analogous to that of the retina. The most exact observations yet made on this point, seem

* For a more detailed sketch of the Comparative Anatomy of the Organ of Hearing, see the Author's "Principles of Comparative Physiology," §§ 711–714.

to be those of the Marquis Corti* on the Cochlear nerve; but the nature of the different parts which he describes, is far from being clearly apparent. This nerve passes-out from the *modiolus* into a series of anastomosing canals excavated in the osseous *lamina spiralis*, and it there comes into relation with a band of vesicular substance, which lies near the edge of the lamina along its whole length. The component vesicles are elongated, having a central and a peripheral extremity; by the former they are connected with the fibres of the cochlear nerve, the connecting filaments being destitute (as elsewhere) of the double contour, and being very fragile; and by the latter they are similarly connected with the fibres which issue-forth from the osseous lamina, to be distributed upon its membranous continuation. These fibres form fasciculi, which traverse the membranous lamina nearly parallel to each other, and anastomose continually with one another, in such a manner as to present the appearance of looped terminations. According to Corti, however, the fibres really pass-on further, losing their double contour, and becoming gradually incorporated, as it were, with the surrounding tissue.†

778. In order to gain any definite idea of the uses of different parts of the Ear, it is necessary to bear in mind that sounds may be propagated amongst solid or fluid bodies in three ways; by *reciprocation*, by *resonance*, and by *conduction*.—1. Vibrations of *reciprocation* are excited in a sounding body, when it is capable of yielding a musical tone of definite pitch, and another body of the same pitch is made to sound near it. Thus if two strings of the same length and tension be placed alongside of each other, and one of them be sounded with a violin-bow, the other will be thrown into reciprocal vibration; or if the same tone be produced near the string in any other manner, as by a flute or a tuning-fork, the same effect will result.—2. Vibrations of *resonance* are of somewhat the same character; but they occur when a sounding body is placed in connection with any other, of which one or more parts may be thrown into reciprocal vibration, even though the tone of the whole be different, or it be not capable of producing a definite tone at all. This is the case, for example, when a tuning fork in vibration is placed upon a sound-board; for even though the whole board have no definite fundamental note,‡ it will divide itself into a number of parts, which will reciprocate the original sound, so as greatly to increase its intensity; and the same sound-

* See his Memoir in Kolliker and Siebold's "Zeitschrift fur wissenschaftliche Zoologie," 1851, band iii. heft 1; also Prof. Kolliker's "Mikroskopische Anatomie," band ii. § 289, and his "Handbook of Human Histology" (Sydenh. Soc. Edit.), vol. ii. p. 407–413.

† Such, also, is the account of their termination given by Messrs. Todd and Bowman, "Physiological Anatomy," vol. ii. p. 81.

‡ The *fundamental note* of a sonorous body is the lowest tone which it yields, when the whole of it is in vibration together. By dividing the body into two or more distinct parts, it may be made to give a great variety of sounds. Thus, if a stretched string be divided by a bridge into two equal parts, each will sound the 8th note or octave above the fundamental note. If it be divided into three parts, each will give the 12th above the fundamental note; if into four, the 15th or double octave will be heard; if into five, the 17th; if into six, the 19th; if into seven, the 20th (the flat seventh above the second octave); if into eight, the 22nd or triple octave. A string forcibly set in vibration has a tendency to sound these harmonics with the fundamental note, by spontaneous division into several distinct segments of vibration, as may be easily made evident, by striking one of the lower keys of the piano, and listening to the sounds heard whilst the fundamental note is dying away.

board will act equally well for tuning-forks of several different degrees of pitch. When a smaller body is used for resonance, however, it is essential that there should be a relation between its fundamental note and that of the sonorous body; otherwise no distinct resonance is produced. Thus, if a tuning-fork in vibration be held over a column of air in a tube, of such a length that the same note would be given by its vibration, its sound will be reciprocated. And if it be held over a pipe, the column of air in which is a multiple of this, the column will divide itself into that number of shorter parts, each of which will reciprocate the original sound, and the total action will be one of resonance. But if the length of the pipe bear no such correspondence with the note sounded by the tuning-fork, no resonance is given by the column of air it contains.—3. Vibrations of *conduction* are the only ones, by which sounds can strictly be said to be propagated. These are distinguishable into various kinds, into which it is not requisite here to inquire. It should be remarked, however, that all media, fluid, liquid, or solid, are capable of transmitting sound in this manner; a vacuum being the only space through which it cannot pass. The transmission is usually much more rapid through solid bodies, than through liquid; and through liquid, than through gaseous. The greatest diminution in the intensity of sound is usually perceived, when a change takes-place in the medium through which it is propagated, especially from the aeriform to the liquid.

779. The detailed application of these principles has been most elaborately worked-out by Prof. Muller; and the following statement of what may be regarded as the present condition of our knowledge of the subject, is little more than an abstract of the results of his experimental investigations; of which the first series bears specially on the case of those animals, which, living immersed in water, receive the sonorous undulations through that medium. The labyrinth of such as possess a distinct organ of hearing, is either entirely enclosed within the bones of the head, as in the Cephalopoda, and in the Cyclostome and Osseous Fishes; or, its cavity being prolonged to the surface of the body, it is there brought into communication with the conducting medium by means of a membrane, besides receiving the vibrations through the medium of the solids of the body, as is the case in Cartilaginous Fishes and Crustacea:— I. Sonorous vibrations, excited in water, are imparted with considerable intensity to solid bodies.—II. Sonorous vibrations of solid bodies are communicated with greater intensity to other solid bodies brought in contact with them, than to water, but with much greater intensity to water, than to atmospheric air.—III. Sonorous vibrations are communicated from air to water with great difficulty, this difficulty very much exceeding that with which they are propagated from one part of the air to another; but their transition from air to water is much facilitated by the intervention of a membrane extended between them.—IV. Sonorous vibrations are not only imparted from water to solid bodies with definite surfaces which are in contact with the water, but are also returned with increased intensity by these bodies to the water; so that the sound is heard loudly in the vicinity of those bodies, in situations where, if it had its origin in the conducting power of the water alone, it would be faint. —V. Sonorous undulations, propagated through water, are partially reflected by the surfaces of solid bodies.—VI. Thin membranes conduct

sound in water without any loss of its intensity, whether they be tense or lax.—VII. When sonorous vibrations are communicated from water, to air inclosed in membranes or solid bodies, a considerable increase in the intensity of the sound is produced, by the resonance of the air thus circumscribed.—VIII. A body of air inclosed in a membrane, and surrounded by water, also increases the intensity of the sound by resonance, when the sonorous undulations are communicated to it by a solid body.

780. Animals living in air are nearly always provided with an opening into the Vestibule, the *fenestra ovalis*, covered by a thin membrane, and generally with a *Tympanic apparatus* also. The following experimental results bear upon the manner in which the Ear of such animals is affected by sound.—IX. Sonorous undulations, in passing from air directly into water, suffer a considerable diminution in their strength; while, on the contrary, if a tense membrane exist between the air and the water, the sonorous undulations are communicated from the former to the latter medium with great intensity.—X. The sonorous vibrations are also communicated, without any perceptible loss of intensity, from the air to the water; when, to the membrane forming the medium of communication, there is attached a short solid body, which occupies the greater part of its surface, and is alone in contact with the water.—XI. A small solid body, fixed in an opening by means of a border of membrane, so as to be moveable, communicates sonorous vibrations, from air on one side, to water or the fluid of the labyrinth on the other, much better than solid media not so constructed. But the propagation of sound to the fluid is rendered much more perfect, if the solid conductor, thus occupying the opening, is by its other end fixed to the middle of the tense membrane, which has atmospheric air on both sides.—The fact stated in IX. is evidently one of great importance in the physiology of hearing; and fully explains the nature of the process in those animals, which receive the sonorous vibrations through air, but which have no tympanic apparatus. In X. we have the elucidation of the action of the fenestra ovalis, and of the moveable plate of the stapes which occupies it, in animals living in air but destitute of tympanic apparatus; this is naturally the case in many Amphibia, and it may happen as the result of disease in the Human subject. In XI. we have a very interesting demonstration of the purpose and action of the tympanum, in the more perfect forms of the auditory apparatus.—We are now prepared to inquire, in somewhat more of detail, into the actions of the different parts of this apparatus; and it will be better to commence with those of the *Middle* and *Internal Ear*, the accessory organs being afterwards considered.

781. The *Membrana Tympani* consists of three layers; an *external* one continuous with the cutis of the external meatus, and consisting of dermoid tissue with a covering of epidermic cells; an *internal*, which is extremely thin, continuous in like manner with the mucous membrane lining the tympanic cavity, and also composed of dermoid tissue and epithelium; and a *middle* layer, which, according to Mr. Toynbee,* may be separated into two distinct laminæ, whose fibres run in contrary directions, those of the external layer (which is the stronger of the two)

* "Philosophical Transactions," 1851.

radiating from the malleus towards the peripheral ring to which they are attached, whilst those of the internal are *annular*. The fibres of which these laminæ are composed, do not appear to be muscular; nor do they present the longitudinal parallel wavy lines characteristic of ordinary fibrous membranes; and they are rendered opaque by acetic acid. Hence, although those laminæ appear to be derived, the external from the periosteum of the meatus, and the internal from that of the tympanic cavity, they differ from it in elementary structure, and seem to have more in common with the elastic tissue. Mr. Toynbee points out the existence of a tubular ligament, enclosing the tendon of the tensor tympani muscle; and considers that the membrane is maintained by this ligament in a state of moderate tension, the assistance of the muscle being only required to augment this.—The function of the *Membrana Tympani* seems obviously to be the reception of sonorous undulations from the air, in such a manner that it may be thrown by them into a reciprocal vibration, which is communicated to the chain of bones. In its usual state, this membrane is scarcely on the stretch; and this is found by experiment to be, for a small membrane, the best condition for the propagation of ordinary undulations. This is easily rendered sensible in one's own person; for an increased tension may be given to the membrana tympani, either by holding the breath and forcing air into the Eustachian tube, so as to distend it from within, or by exhausting the cavity, so as to cause the external air to make increased pressure upon it; and in either case, the hearing is immediately found to become indistinct. It is observed, however, that grave and acute sounds are not equally affected by this action; for the experimenter renders himself deaf to grave sounds, whilst acute sounds are heard even more distinctly than before. This fact is readily understood, by referring to the laws of Acoustics already mentioned. The greater the tension to which the membrana tympani is subjected, the more acute will be its fundamental tone; and as no proper reciprocation can take-place in it, to any sound *lower* than its fundamental tone, its power of repeating perfectly the vibrations proper to the deeper notes will diminish. The nearer a sound approaches to the fundamental note proper to the tense membrane, the more distinctly will it be heard. On the other hand, when the membrane is in its naturally-relaxed condition, its fundamental note is very low, and it is capable of repeating a much greater variety of sounds; for, when it receives undulations of a higher tone than those to which the whole membrane would reciprocate, it divides itself into distinct segments of vibration, which are separated by lines of rest; and every one of these reciprocates the sound,* at the same time rendering it more intense by multiplication (§ 778). These facts enable us to understand the influence of the *tensor tympani* muscle, in augmenting the tension of the membrane, and thus enabling it to vibrate in reciprocation to sounds having a great

* This is very easily proved by experiment on a membrane stretched over a resonant cavity; for if light sand be strewed upon it, and a strong musical tone be produced in its vicinity, the membrane will immediately be set in vibration, not as a whole (unless its fundamental note be in unison with that sounded), but in different segments, of which every one reciprocates the sound; from the vibrating parts, the sand will be violently thrown off, but it will settle on the intermediate lines of rest, which are known as the *nodal* lines, forming a variety of curious figures.

variety of fundamental notes. It appears to be antagonized by the *stapedius*, the contraction of which seems to diminish the tension of the membrana tympani, and to take-off pressure from the fluid of the labyrinth. These two muscles conjointly may be considered to regulate the transmission of sonorous undulations to the fluid of the internal sac, preventing it from being too violently affected by loud sounds, in the same manner that the iris regulates the admission of light to the eye (§ 757), and the analogy extends also to their nervous supply, the stapedius being excited to action by a branch of the Facial, whilst the tensor tympani receives its nerves from the Otic ganglion (§ 825).* They are probably put into frequent action when we are *listening* for faint sounds, so as to bring the tympanum into the state of tension best adapted to reciprocate them; whilst by a like preparation, the concussive effects of a loud sound that is *anticipated*, are more effectually moderated than when it strikes the ear without warning. It is probably owing to an imperfect action of these muscles, that some persons are deaf to grave sounds, whilst they readily hear the more acute.

782. The uses of the *Tympanic Cavity* are very obvious. One of its purposes is to render the vibrations of the membrane quite free; and the other, to isolate the chain of bones, in such a manner as to prevent their vibrations from being weakened by diffusion through the surrounding solid parts. As to the objects of the *Eustachian Tube*, opinions have been much divided. Many of these opinions, however,—such as the one most commonly entertained, that it serves the same purpose as the hole in an ordinary drum, removing an impediment to the free vibration of the membrane, that would be offered by the complete enclosure of the air within,—are at once negatived by the fact, which seems to have been demonstrated by Mr. Toynbee, that the guttural orifice of the tube is usually *closed*, being only opened during the act of swallowing.† The principal object of the Eustachian tube (which is always found where there is a tympanic cavity) seems to be, the maintenance of equilibrium between the air within the tympanum and the external air; so as to prevent inordinate tension of the membrana tympani, which would be produced by too great or too little pressure on either side, and the effect of which would be imperfection of hearing. It also has the office of conveying-away mucus secreted in the cavity of the tympanum, by means of the vibratile cilia which clothe its lining membrane; and the deafness consequent on occlusion of this tube, is in part explicable by the accumulation which then takes-place in the cavity.

783. From what has been stated, it is evident that sonorous undulations in the air will be propagated to the fluid contained in the labyrinth,—through the tympanum, the chain of bones, and the membrane of the *fenestra ovalis* to which the stapes is attached,—without any loss, but rather an increase, of intensity. Why water should be chosen as the medium through which the impression is to be made upon the nerve, it is impossible for us to say with anything like certainty, in our present state of ignorance as to the physical character of that impression. But

* See Mr. C. Brooke in "Lancet," 1843, p. 380; and Mr. Toynbee in "Brit. and For. Med.-Chir. Rev.," vol. xi. p. 255.

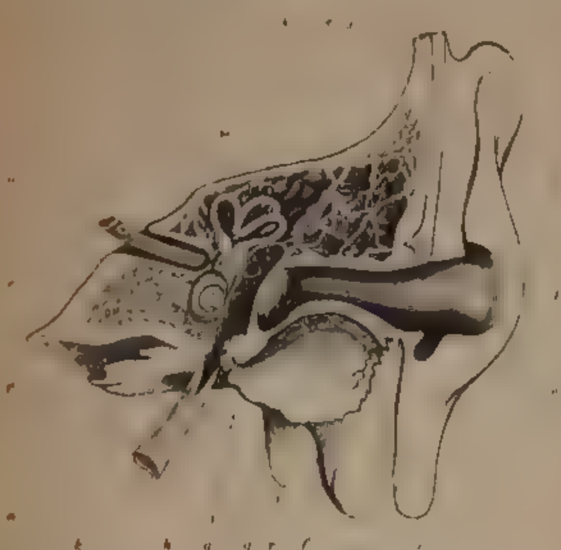
† Loc. cit., and "Proceedings of Royal Society," 1852.

the problem being to communicate to water the sonorous undulations of air, the experimental results already detailed satisfactorily prove that—whilst this may be accomplished, in a degree sufficient for the wants of the inferior animals, by the simple interposition of a tense membrane between the air and the fluid,—the tympanic apparatus of the higher classes is most admirably adapted for this purpose. The fenestra ovalis is not, however, the only channel of communication between the tympanum and the labyrinth; for there is in most animals, a second aperture, the *fenestra rotunda*, leading into the cochlea, and simply covered with a membrane. It is generally supposed that, the labyrinth being filled with a nearly incompressible fluid, this second aperture is necessary to allow the free vibration of that fluid; the membrane of the fenestra rotunda being made to bulge-out, as that of the fenestra ovalis is pushed-in. It may be easily shown by experiment, however, as well as by reference to comparative anatomy, that no such contrivance is necessary; for sonorous undulations may be excited in a non-elastic fluid, completely inclosed within solid walls at every part, except where these are replaced by the membrane through which the vibrations are propagated; and this is precisely the condition, not only of Invertebrated animals, but even of Frogs; in which last a tympanic apparatus exists, without a second orifice into the labyrinth. Moreover it is certain, that the vibrations of the air in the cavity of the tympanum, must of themselves act upon the membrane of the fenestra rotunda; and this is perhaps the most direct manner in which the fluid in the cochlea will be affected, although it will ultimately be thrown into much more powerful action, by the transmission of vibrations from the vestibule. For it has been satisfactorily determined by experiment (XII.), that vibrations are transmitted with very much greater intensity to water, when a tense membrane, and a chain of insulated solid bodies capable of free movement, are successively the conducting media, than when the media of communication between the vibrating air and the water are the same tense membrane, air, and a second membrane:—or, to apply this fact to the organ of hearing, the same vibrations of the air act upon the fluid of the labyrinth with much greater intensity, through the medium of the chain of auditory bones and the fenestra ovalis, than through the medium of the air of the tympanum and the membrane closing the fenestra rotunda.—The fenestra rotunda is not to be considered as having any peculiar relation with the cochlea; since, in the Turtle tribe, the former exists without the latter.

784. It is obviously in the *Labyrinth* as a whole, that the sonorous vibrations are brought to bear upon the Auditory nerve spread-out to receive them. In regard to the special functions of particular parts of the labyrinth, however, no certainty can be said to exist. The membrane which lines its cavities not only contains a liquid (the *endo-lymph*), but is also separated from the osseous wall by another collection of liquid, the *peri-lymph*; so that it is suspended, as it were, in a liquid which bathes both its surfaces. In the cavity of the *Vestibule*, which is subdivided by a membranous partition into two, are found small masses of concretionary particles, collectively named *otoconia* or ear-powder; these are obviously the rudiments of the *otoliths*, or ear-stones, whose presence, in animals with a less perfect auditory apparatus, seems needful to intensify

the undulations.—It is commonly supposed that the *Semicircular Canals* have for their peculiar function, to receive the impressions by which we distinguish the *direction* of sounds; and it is certainly a powerful

Fig. 105.



Vertical Section of the *Human Ear*, the internal portions on an enlarged scale; *a*, *b*, *c*, external ear; *d*, entrance to auditory canal, *f*; *e*, *e*, petrous portion of temporal bone; *g*, membrana tympani; *h*, cavity of the tympanum, the chain of bones being removed; *i*, opening from this cavity into the cells *j*, excavated in the bone; on the side opposite the membrana tympani are seen the fenestra ovalis and rotunda; *k*, Eustachian tube; *l*, vestibule; *m*, semicircular canals; *n*, cochlea; *o*, auditory nerve; *p*, canal for carotid artery; *q*, part of glenoid fossa; *r*, styloid process.

argument in support of this view, that, in almost every instance in which these parts exist at all, they hold the same relative positions as in Man, their three planes being nearly at right angles to one another. The idea, however, must be regarded as a mere speculation, the value of which cannot be decided without an increased knowledge of the laws according to which sonorous vibrations are transmitted; but it receives a certain degree of confirmation from the curious movements witnessed by M. Flourens after section of one or other of these canals (§ 531).— Regarding the special function of the *Cochlea*, there is precisely the same uncertainty. This part of the organ is peculiar in one respect, that the expansion of the auditory nerve is here spread-out (within the lamina spiralis) in closer proximity with the bone itself, than it is in any other part of the labyrinth; and moreover the peri-lymph is here deficient, so that the membranous lining of the cochlea is in absolute contact with its osseous wall. It is not easy to see, however, what can be the peculiar object of this disposition in regard to the function of hearing. It has been surmised by M. Dugès, that by the Cochlea we are especially enabled

to estimate the *pitch* of sounds, particularly of the voice; and he adduces, in support of this idea, the fact, that the development of the cochlea follows a very similar proportion with the compass of the voice. This is much the greatest in the Mammalia; less in Birds; and in Reptiles which have little true vocal power, the cochlea is reduced to its lowest form, disappearing entirely in the Amphibia. That there should be an acoustic relation between the voice and ear of each species of animal, cannot be regarded as improbable; but the speculation of M. Dugès can at present only be received as a stimulus to further inquiry.

785. We have now to consider the functions of the accessory parts,—the *External Ear*, and the *Meatus*. The Cartilage of the external ear may propagate sonorous vibrations in two ways; by reflection, and by conduction. In reflection, the concha is the most important part, since it directs the reflected undulations towards the tragus, whence they are thrown into the auditory passage. The other inequalities of the external ear cannot promote hearing by reflection; and the purpose of the extension of its cartilage is evidently to receive the sonorous vibrations from the air, and to conduct them to its source of attachment. In this point of view, the inequalities become of importance; for those elevations and depressions upon which the undulations fall perpendicularly, will be affected by them in the most intense degree; and in consequence of the varied form and position of these inequalities, sonorous undulations, in whatever direction they may come, must fall advantageously upon some of them.—The functions of the Meatus appear to be threefold. The sonorous undulations entering from the atmosphere are propagated directly, without dispersion, to the membrana tympani: the sonorous undulations received on the external ear, are conveyed along the walls of the meatus to the membrana tympani; whilst the air which it contains, like all insulated masses of air, increases the intensity of sounds by resonance. That, in ordinary hearing, the direct transmission of atmospheric vibrations to the membrana tympani, is the principal means of exciting the reciprocal vibrations of the latter, is sufficiently evident; the undulations which directly enter the passage, will pass straight-on to the membrane; while those that enter obliquely will be reflected from side to side, and at last will fall obliquely on the membrane, thus perhaps contributing to the notion of direction. The power of the lining of the meatus to conduct sound from the external ear, is made evident by the fact, that, when both ears are closely stopped, the sound of a pipe having its lower extremity covered by a membrane, is heard more distinctly when it is applied to the cartilage of the external ear itself, than when it is placed in contact with the surface of the head. The resonant action of the air in the tube is easily demonstrated, by lengthening the passage by the introduction of another tube; the intensity of external sounds, and also that of the individual's own voice, as heard by himself, is then much increased.

786. Many facts prove, however, that the fluid of the Labyrinth may be thrown into vibration in other ways than by the Tympanic apparatus. Thus in Osseous Fishes, it is only by the vibrations transmitted through the bones of the head, that hearing can take place. There are many persons, again, who can distinctly hear sounds which are thus transmitted to them; although, through some imperfection of the tympanic

apparatus, they are almost insensible to those which they receive in the ordinary way. It is evident, where this is the case, that the nerve must be in a state fully capable of functional activity; and, on the other hand, where sounds cannot thus be perceived, there will be good reason to believe that the nerve is diseased.

787. A single impulse communicated to the Auditory nerve, in any of the foregoing modes, seems to be sufficient to excite the momentary sensation of *sound*, but most frequently a series of such impulses is concerned, there being but few sounds which do not partake, in a greater or less degree, of the character of a *tone*. Any continuous sound or tone is dependent upon a succession of impulses; and its acuteness or depth is governed by the rapidity with which these succeed one another It is not difficult to ascertain by experiment, what number of such impulses or undulations are required, to give every tone which the ear can appreciate. Thus, if a circular plate, with a number of apertures at regular intervals, be made to revolve over the top of a pipe through which air is propelled, a succession of short *puffs* will be allowed to issue from this; and, if the revolution be sufficiently rapid, these impulses will unite into a definite tone. In the same manner, if a spring be fixed near the edge of a revolving toothed wheel, in such a manner as to be caught by every tooth as it passes, a succession of *clicks* will be heard, and these too, if the revolution of the wheel be sufficiently rapid, will produce a tone. The number of apertures in the plate which pass the orifice of the pipe in a given time, or the number of teeth which pass the spring, being known, it is easy to see that this must be the number of impulses required to produce the given tone. Each impulse produces a double vibration, forwards and backwards (as seen when a string is put in vibration, by pulling it out of the straight line); hence the number of single vibrations is always double that of the impulses.—The maximum and minimum of the intervals of successive pulses, still appreciable by the ear as determinate sounds, have also been determined by M. Savart, more satisfactorily and more accurately than had previously been done. If their intensity be great, sounds are still audible which result from the succession of 24,000 impulses in a second; and this, probably, is not the extreme limit to the acuteness of sounds perceptible by the ear. From some observations of Dr. Wollaston's, it seems probable that the ears of different individuals are differently constituted in this respect; some not being able to hear very acute tones produced by Insects, or even Birds, which are distinctly audible to others. Again, the sound resulting from 16 impulses per second, is not, as has been usually supposed, the lowest appreciable note; on the contrary, M. Savart has succeeded in rendering tones distinguishable, which are produced by only 7 or 8 impulses in a second; and continuous sounds of a still deeper tone could be heard, if the individual pulses were sufficiently prolonged. In regard, however, to the precise time during which a sonorous impression remains upon the ear, it is difficult to procure exact information, since it departs more gradually than do visual impressions from the eye. This is certain, however, that it is much longer than the interval between the successive pulses in the production of tones, since it was found by M. Savart, that one or even several teeth might be removed from the toothed wheel, without a perceptible break in its sound,—showing that, when the tone

was once established, the impression of it remained during an intermission of some length.

788. The power of distinguishing the *direction* of sounds appears to be, in Man at least, for the most part acquired by habit; for it is some time before the infant seems to know anything of the direction of noises which attract his attention. Our judgment as to this point is probably assisted, in most cases, by a difference in the intensity of the sensations received through the two ears respectively; but since we have a certain power of appreciating direction when one ear alone is used, this power must depend upon an exercise of perceptive discrimination (which is probably acquired, rather than intuitive,) in regard to the impressions which we receive through its means; and it has been already mentioned, that the Semicircular canals (§ 781) appear to furnish the instrumentality by which our minds are enabled to take cognizance of such differences.—The idea of the *distance* of the sonorous body is another acquired perception, depending principally upon the loudness or faintness of the sound, when we have no other indications to guide us. In this respect there is a great similarity between the perception of the distance of an object, through the Eye by its size, and through the Ear by the intensity of its sound. When we are acquainted with the usual intensity of its sound, we can judge of its distance; and *vice versâ*, when we know its distance, we can at once form an idea of its real strength of tone from that with which our ears are impressed. In this manner, the mind may be affected with corresponding deceptions through both senses: for as, in the Phantasmagoria, the figure being gradually diminished whilst its distance remains the same, it appears to the spectators to recede (the illusion being more complete if its brightness be at the same time diminished); so the effect of a distant full military band gradually approaching, may be alike given by a corresponding *crescendo* of concealed instruments. It is upon the complete imitation of the conditions which govern our ideas of the intensity and direction, as well as of the character, of sounds, that the deceptions of the Ventriloquist are founded.

789. The Auditory sense, like the visual, may vary considerably among different individuals, both as regards its general acuteness, and as respects its discriminative power for particular classes of impressions. Much depends upon the *habit of attention* to its indications; and thus it comes to pass, that the power of hearing very faint sounds and of recognizing their source, becomes augmented to a wonderful degree in those individuals who are obliged to trust to the knowledge thus acquired for the direction of their own actions; whilst, in like manner, the power of distinguishing slight differences in the pitch of sounds, may be so cultivated (when it is not congenitally deficient) as to attain an intensity that seems very extraordinary to those who have not accustomed themselves to listen for them. The general cultivation of this sense is perhaps most remarkable in blind persons, who have enabled themselves, by reliance upon it, to walk about freely, even in the crowded thoroughfares of the Metropolis; and who are not only able to judge of the habits of individuals whom they meet, by the sound of their footsteps (at once recognizing, for instance, the footstep of a policeman on duty), but can even tell when they are passing a stationary object (such as a lamp-post), provided it be as high as the ear or nearly so, by the reverberation of the sound of their own footsteps, and can

discriminate between a lamp-post and a man standing still in the position of one, by the same means.* The effect of habitual attention in increasing the discriminative power for impressions of one particular kind, is perhaps best seen in the ability which is possessed by certain Conductors of orchestral performances, to detect the slightest departure from time or tune in the sound of any one of (perhaps) a hundred instruments that are simultaneously sounding, and to fix without hesitation upon the faulty instrumentalist.—There seems to be a great analogy between the power of distinguishing *colours*, and that of discriminating *musical tones;* and whilst we find that some persons are endowed with the latter, which is commonly known as a 'musical ear,' in a degree that renders it a source of great discomfort to them (since every discordant sound is a positive torment), others are altogether destitute of it,—the deficiency being very analogous to the 'colour-blindness' formerly described (§ 770). It is not a little curious, that the two defects are occasionally co-existent in the same individuals.†

790. Some facts of much interest have lately been ascertained, in regard to an occasional difference in the rapidity of the perception of sensory impressions, received through the Eye and through the Ear respectively. These facts are the result of comparisons made amongst different Astronomical observers, who may be watching the same visual phenomenon, and 'timing' their observations by the same clock; for it has been remarked, that some persons see the same occurrence, a third or even a half of a second *earlier* than others. There is no reason to suppose from this, however, that there is any difference in the rate of transmission of the sensory impressions in the two nerves. The fact seems rather to be, that the Sensorium does not readily perceive two impressions of different kinds with equal distinctness; and that, when several such impressions are made on the senses at the same time, the mind takes cognizance of one only, or perceives them in succession. When, therefore, both sight and hearing are directed simultaneously to two objects, the communication of the impression through one sense will necessarily precede that made by the other. The interval between the two sensations is greater in some persons than in others; for some can receive and be conscious of many impressions, seemingly at the same moment; whilst in others a perceptible space must elapse. The 'personal equation' of each observer in an Observatory, has, therefore, to be determined and allowed-for.

791. Amongst other important offices of the sense of Hearing, is that of supplying the sensations by which the Voice is regulated. It is well known that those who are born entirely deaf, are also dumb; that is, they do not spontaneously or imitatively form articulate sounds, though not the least defect may exist in their organs of voice. Hence it appears that the vocal muscles are usually guided in their action by the sensations received through the Ears, in the same manner as other muscles are guided by the sensations received through themselves; but when the former are deficient, the action of the vocal muscles may be guided by the latter (§ 542).

* See the account of a blind boot-lace-seller given by Mr. H. Mayhew, in his "London Labour and the London Poor," vol. i., p. 402.

† See a collection of such cases by Dr. Pliny Earle, in "Amer. Journ. of Med. Sci.," vol. xxxv.

CHAPTER XIII.

OF MUSCULAR MOVEMENTS.

1. *Voluntary and Involuntary Movements.*

792. By far the larger proportion of the Muscular apparatus of the Human Body, may be considered in the light of an instrument whereby the Nervous System is enabled to give motion to its parts, and thus to effect those changes in its relation to the external world, which are requisite for its physical well-being, or which are the expressions of its psychical powers. There is probably no part of the Muscular system, which is altogether beyond the pale of Nervous agency, but a tolerably-definite line of demarcation may be drawn, both structurally and functionally, between the two primary subdivisions of this system, in the first of which, the *Muscular apparatus of Organic Life*, the actions are but little dependent upon nervous agency; whilst in the second, the *Muscular apparatus of Animal Life*, scarcely any action takes-place, but what is called-forth by nerve-force.—The *First* group consists of the Muscular envelopes which surround the various open cavities of the body, and which form part of its general investment, its office being to aid in the performance of the Organic functions, by giving motion to the contents of the cavities, or by maintaining a proper state of tension around them: and it is composed almost entirely of the *non-striated* or *smooth* form of muscular fibre (PRINC. OF GEN. PHYS.), the only marked exception being in the case of the Heart. Under this category rank the proper muscular coat of the alimentary canal, from its commencement in the œsophagus to its termination at the anus, the muscular coats of the gland-ducts which discharge themselves into this, the muscular fibres of the trachea and bronchial tubes; the muscular substance of the heart, and the muscular coats of the blood-vessels and absorbents generally; the muscular walls of the ureters, bladder, urethra, and vasa deferentia in the male, and of the ureters, bladder, urethra, fallopian tubes, uterus, and vagina of the female; and finally, the muscular substance of the skin. With regard to nearly all these parts, which are supplied with nerves (for the most part) by the Sympathetic (Chap. XV.) rather than by the Cerebro-spinal system, it is difficult to obtain evidence that Nervous agency has any participation in their usual operations, and all the evidence yet adduced tends only to show, that contractions *may be* excited through this instrumentality, *not* that they *habitually are* so, their ordinary contractions being produced either by their own motility (§ 242), or by stimuli directly applied to themselves.—The *Second* of the above-named divisions consists of all those Muscles which are usually styled 'voluntary,' since they can be put or retained in action by the mandates of the Will, through the instrumentality of the Cerebro-spinal system of nerves; but besides these, it includes a large group of muscles (those, namely, that are concerned in the acts of Deglutition, Respiration,

Vomiting, Parturition, Defecation, and Urination), over which the Will exerts only a partial control, their activity being usually called forth automatically. It would seem as if this group were placed under the same conditions, as regards their dependence on Nervous agency, with those more properly termed voluntary, in order that the Will, which is altogether powerless over the Muscular apparatus of Organic Life, may bring their operations into harmony with the general requirements of the system; the functions in question being those which constitute (so to speak) the meeting points between the Organic and the Animal life. For as we descend through the Zoological scale, we find that they lose more and more of the character they possess in Man, becoming more and more exclusively automatic, and at last being even transferred from the more elaborate mechanism of muscular contraction, to the simple operation of ciliary vibration.* Nearly all those muscles in the Human body, which are ordinarily called into action by the Cranio-Spinal nerves, are composed of *striated* fibre; the most remarkable exception being the muscular structure of the Iris. And it is peculiarly characteristic of them, that whilst forcible and united contractions of all the fasciculi at once, are called-forth by irritating their nerves, the effect of direct stimulation is limited to the fasciculus irritated.

793. It is obvious from what has preceded, that the system of classifying the Muscles under the categories of *voluntary* and *involuntary*, cannot be consistently maintained. It is quite true that all the Muscles of Organic Life may be truly styled 'involuntary;' for although they are capable of being influenced by emotional and ideational states of mind (§ 829), yet the Will cannot exert any direct influence upon them, only affecting them indirectly by its power of determining these states. But over those Muscles, also ministering to the Organic functions, and doing so in obedience to impulses purely automatic, which are called into action by the Cranio-Spinal nerves, the Will, as we have seen, exerts some power; and such, therefore, cannot be properly regarded as involuntary, since the Will can influence their state; whilst they are far from being truly voluntary, since the Will cannot control their tendency to automatic action beyond a certain limited amount (§ 302). On the other hand, every one of the Muscles usually styled voluntary, because ordinarily called into action by the Will, is liable to be thrown into action involuntarily, either by an Excito-motor stimulus, as in tetanic convulsions, or by Consensual action, as in tickling, or Emotionally, as in laughter or rage, or simply Ideationally, as in somnambulism and analogous states. Hence although there are certain groups of muscles which are more frequently acted-on by the Will than by any other impulse, and certain others which are more frequently played-on by the Emotions, and so-on, it becomes obvious that every muscle called into contraction by the Cranio-Spinal nervous system, is capable of receiving its stimulus to movement from *any* of these sources, the nerve-force transmitted along the motor-fibres, being issued either from the Spinal Cord, from the Sensory Ganglia, or from

* Thus in the Oyster and other Bivalve Mollusks, which have a complicated digestive, circulating, and respiratory apparatus, food is brought to the mouth, fecal matters are expelled from the anus, and a constant current of water is made to sweep over the respiratory surface, entirely by ciliary motion.

the Cerebrum, as the case may be, but being in its nature and effects the same in every instance.

794. The grouping or combination of Muscular actions, which takes place in almost every movement of one part of the body upon another, must be attributed, not to any peculiar sympathy among the Muscles themselves, but to the mode in which they are acted on by the Nervous Centres. This is most obviously the case with regard to those of the primarily-automatic class; but it can scarcely be doubtful as to those of the secondarily-automatic kind (§ 514), such as walking, which, though at first directed by the Will, come by habit to be performed under conditions essentially the same with the preceding, and when it is borne in mind that even in voluntary movements the Will cannot single-out any one muscle from the group with which it usually co-operates, so as to throw this into separate contraction, but is limited to determining the result (§ 545), it seems pretty obvious that even here the grouping is effected by the endowments of those Automatic centres from which all the motor impulses immediately proceed to the muscles, and not by Cerebral agency. In fact, the whole process by which we acquire the power of adapting our muscular actions to the performance of some new kind of movement,—as in the case of an infant learning to walk, a child learning to write, an artizan learning some occupation which requires nice manipulation, a musical performer learning a new instrument, and so on,—is found, when attentively studied, to indicate that the Will is far from having that direct and immediate control over the contractions of the Muscles, which it is commonly reputed to possess; and that the operation really consists in the gradual establishment of a new grouping of the separate actions, in virtue of which, the stimulus of a Volitional determination, acting under the guidance of the muscular sensations (§ 541), henceforth calls into contraction the group of muscles whose agency is competent to carry that determination into effect. For however amenable any set of muscles (as those of the arm and hand) may have become to the direction of the Will, in any operations which they have been previously accustomed to perform, it is only after considerable practice that they can be trained to any method of combined action which is entirely new to them; and even if we attempt to bring our anatomical knowledge into use for such a purpose, by mentally fixing upon certain muscles whose action we wish to intensify and to associate with those of others, we find that such a method of proceeding affords no assistance whatever, but rather tends to impede our progress, by drawing off the attention from the 'guiding sensations' (visual, muscular, &c.), which are the only regulators that can be depended upon for determining the due performance of the volitional mandate. Hence we are led by these considerations, as by those stated in the preceding paragraph, to the conclusion, that the agency which directly affects the muscles is of the same kind, and that it operates under the same instrumental conditions, whatever be the primal source of the motor power. And in watching the gradual acquirement of the capacity for different kinds of movement, during the periods of Infancy and Childhood in the Human subject, we find everything to confirm this conclusion. For it becomes obvious that the acquirement of Voluntary power over the movements of the *limbs*, is

just as gradual as it is over the direction of the *thoughts* (§ 677); all the activity of the *body*, as well as of the *mind*, being in the first instance automatic, and the Will progressively extending its domination over the former, as over the latter, until it brings under its control all those muscular movements which are not immediately required for the conservation of the body, and turns them to its own uses.*

2. *Of the Symmetry and Harmony of Muscular Movements.*

795. It might have been not unreasonably supposed, *à priori*, that those muscles would have been most readily put into simultaneous contraction, which correspond to each other on the two sides of the body; in other words, that *symmetrical* movements would be those most readily performed. Such, however, is by no means the case; for in many of our most familiar actions, we consentaneously exert different muscles on the two sides of the body. Thus, in ordinary walking, we advance one leg whilst we push-backwards (so as to urge the body forwards) with the other; and in the swinging of the arms, which is in most persons a natural part of this mode of locomotion, the arms of the two sides move forwards and backwards alternately, and the arm of either side is advanced, not with the leg of its own side, but with that of the opposite side,—any other combination being felt as unnatural, and being only performed by a conscious effort. Now it is plain that this grouping of the muscular movements arises out of its *felt* conformity to the end in view, and that it is regulated by the guiding sensations which indicate to us the progression and balance of the body. The infant, in learning to walk, is prompted by an instinctive tendency to put one foot before the other, as may be noticed at a very early period, when it is first held so as to feel the ground with its feet; and in attempting to balance itself when first left to stand alone, it moves its arms with a like intuitive impulse, not based upon experience. All that experience does, in either case, is to give that precise adjustment to the muscular action, which makes it perfectly conformable to the indications afforded by the muscular sensations. Thus, if we advance each arm with its corresponding leg, we feel that the balance of the body is not nearly as readily maintained, as it is when we advance the arm with the leg of the opposite side; and thus, without any design or voluntary determination on our own parts, the former comes to be our settled habit of action. This kind of adjustment,

* The aptitude which is acquired by practice, for the performance of certain actions that were at first accomplished with difficulty, seems to result as much from a structural change which the continual repetition of them occasions in the Muscle, as in the habit which the Nervous system acquires of exciting the movement. Thus almost every person learning to play on a musical instrument, finds a difficulty in causing the two shorter fingers to move independently of each other and of the rest; this is particularly the case in regard to the ring-finger. Any one may satisfy himself of the difficulty, by laying the palm of the hand flat on a table, and raising one finger after the other, when it will be found, that the ring-finger can scarcely be lifted without disturbing the rest, evidently from the difficulty of detaching the action of the portion of the *extensor communis digitorum*, by which the movement is produced, from that of the remainder of the muscle. Yet to the practised musician, the command of the Will over all the fingers becomes nearly alike; and it can scarcely be doubted that some change in the structure of the muscle, or a new development of its nerve-fibres, takes place, which favours the isolated operation of its several divisions.

in the case before us, is by no means limited to the muscles of the limbs; for there is scarcely any muscle of the trunk or head, that is not exerted with some degree of consentaneous energy, however unconsciously to ourselves, in the act of walking. The difficulty which would attend the voluntary harmonization of all these separate actions, is remarkably evinced by the fact, that no mechanist, however ingenious, has ever succeeded in constructing an automaton that should *walk* like Man; the alternate shifting of the centre of gravity from one side to the other, upon so small a base as the human foot affords, simultaneously with the movement in advance, constituting the great difficulty of biped progression. But all this adjustment is effected in our own organisms, *for* us, rather than *by* us; the act of harmonization, when once fully mastered, being attended with no effort to ourselves; but the whole series of complex movements being performed in obedience to the simple determination *to walk*, under the automatic guidance of the senses, which instantly reveal to us any imperfection in the performance.—The same view extends itself readily to other combinations of dissimilar and non-symmetrical movements, which are less *natural* to Man, but which may be readily acquired *artificially* if they all harmonize in a common purpose, and are under the guidance of the same set of sensations. Thus, the performer on the Organ uses the several fingers of his two hands to execute as many different movements (in very different positions, it may be) on the 'manual' keys, one of his feet may be on the 'swell' pedal, and the other may be engaged in playing on the 'pedal' keys; but all these diverse actions are harmonized by their relation to the same set of auditory sensations; and if the result be not that which the performer anticipated, an immediate correction is made.

796. It would be easy to multiply instances of the same kind, all illustrative of the general principle, that the facility with which we voluntarily combine different movements is chiefly determined, not by their *symmetrical* character, but by their *conformableness to a common end*, and by the *harmony of their guiding sensations* with reference to that end;* but it will be desirable to dwell particularly on the *Movements of the Eye*, as presenting certain points of peculiar interest, some of which have an important bearing on Surgical practice.—It will be recollected that, in the Human Orbit, six muscles for the movements of the eyeball are found, the four Recti, and the two Oblique muscles. The precise actions of these are not easily established by experiment on the lower animals; for in all those which ordinarily maintain the horizontal position, there is an additional muscle, termed the *retractor*, which embraces the whole posterior portion of the globe, and passes backwards to be

* Two simple examples, however, may be cited, of the difficulty which attends the simultaneous performance of movements that are not harmonious. If we attempt to elevate one eyelid whilst we are depressing the other, we find that a considerable effort is required to accomplish the action, although the elevation or depression of both eyelids together is performed with so little effort that we are scarcely conscious of it; and the difficulty is increased if we half shut both eyes, and then try to close one and to open the other. So if we try to move our two hands, as if they were *simultaneously* winding cord *in opposite directions* upon two reels placed in front of us, we shall find ourselves unable to do so without a constant exercise of the attention, and even then but slowly and with difficulty; although the very same movements may be *separately* performed, or both hands may be made thus to move *in the same direction*, with the greatest facility.

attached to the bottom of the orbit.* If the origin and insertion of the four *Recti* muscles be examined, however, no doubt can remain that each of them, acting singly, is capable of causing the globe to revolve in its own direction,—the superior rectus causing the pupil to turn upwards,—the internal rectus causing it to roll towards the nose, and so on. A very easy and direct application of the laws of mechanics will further make it evident to us, that the combined action of any two of the Recti muscles must cause the pupil to turn in a direction intermediate between the lines of their single action; and that *any* intermediate position may thus be given to the eyeball by these muscles alone. This fact, which has not received the attention it deserves, leads us to perceive that the Oblique muscles *must* have some supplementary function. It may be objected that this is a theoretical statement only; and that there may be some practical obstacle to the performance of diagonal movements by the Recti muscles, which renders the assistance of the Obliques essential for this purpose. But to this it may be replied, that *no single* muscle can direct the ball either downwards and inwards, or upwards and outwards: and that, as we have good reason to believe *these* movements to be effected by the combination of the Recti muscles, there is no reason why *the other* diagonal movements should not also be due to them.—The most probable account of the functions of the *Oblique* muscles of the eye, seems to be that which was long ago suggested by John Hunter, and which has received confirmation from the experiments of Dr. G. Johnson.† It has been just shown that the action of the Recti muscles upon the pupil, is such as to cause it to *revolve* in any given direction: and this is put in force, not merely to alter the range of vision, the head remaining stationary; but also to keep the range of vision the same, and to cause the images of the objects upon which our gaze is fixed, still to fall upon the same parts of the retinæ, by maintaining the position of the eyes when the head is moved upwards, downwards, from side to side, or in any intermediate direction (§ 546). But these muscles are not able to *rotate* the eyeball upon its antero-posterior axis; and such rotation is manifestly necessary to preserve the fixed position of the eyeball, and consequently to keep the image of the object under survey upon the same part of the retina, when the head is inclined sideways, or is bowed towards one shoulder and then towards the other. It appears from the experiments of Dr. G. Johnson, that the action of the Oblique muscles is exactly adapted to produce such a rotation: the Inferior oblique, in its contraction, causing the eyeball to move upon its antero-posterior axis, in such a manner that a piece of paper, placed at the outer margin of the cornea, passes

* This muscle is most developed in Ruminating animals, which, during their whole time of feeding, carry their heads in a dependent position. In most Carnivorous animals, instead of the complete hollow muscular cone (the base inclosing the eyeball, whilst the apex surrounds the optic nerve), which we find in the Ruminants, there are four distinct strips, almost resembling a second set of recti muscles, but deep-seated, and inserted into the posterior instead of the anterior portion of the globe. It is obvious that the actions of these must greatly affect the results of any operations which we may perform upon the other muscles of the Orbit; and, as it is impossible to divide the former, without completely separating the eye from its attachments, we have no means of correcting such results, but by reasoning alone. Experiments upon animals of the order Quadrumana, most nearly allied to Man, would be more satisfactory; as in them, the retractor muscle is almost or entirely absent.

† "Cyclopædia of Anatomy and Physiology," vol. iii. p. 790.

downwards and then inwards towards the nose; and the Superior oblique effecting precisely the reverse action, the paper at the outer margin of the cornea passing first upwards and then inwards. There was not the slightest appearance, in these experiments, of elevation, depression, abduction, or adduction, of the cornea, as a result of the action of the Oblique muscles; all these movements being attributable to the Recti alone.*

797. On studying the Voluntary movements of the Eyeballs, we are led to perceive that they are not so much *symmetrical* as *harmonious*, that is to say, the corresponding muscles on the two sides are rarely in action at once; whilst such a harmony or *consent* exists between the actions of the muscles of the two orbits, that they work to one common purpose, namely, the direction of both eyes towards the required object. They may be arranged under two groups; the first comprising those which are alike harmonious and symmetrical; the second including those which are harmonious but not symmetrical. To the *first* group belong the following.—1. *Both* eyeballs are *elevated*, by the contraction of the two Superior Recti.—2. *Both* eyeballs are *depressed*, by the conjoint action of the Inferior Recti muscles.—3. *Both* are drawn directly *inwards*, or *inwards* and *downwards*, as when we look at an object placed on or near the nose; this movement is effected by the action of the Internal Recti of the two sides, with or without the Inferior Recti. It is evidently symmetrical, but might seem at first sight not to be harmonious, because the eyes do not move together towards one side or the other; it is, however, really harmonious, since it directs their axes towards the same point.†—Now it is to be observed, with regard to these movements, that we can never effect them in antagonism with each other, or with those of other muscles. We cannot, for example, raise one eye and depress the other; nor can we raise or depress one eye, when we adduct or abduct the other. The explanation of this will be found in the fact, that we can never, by so doing, direct the eyes to the same point.—The harmonious but unsymmetrical movements, forming the *second* class, are those in which the Internal and External Recti of the two sides are made to act together, either alone, or in conjunction with the Superior and Inferior Recti. They are as follows.—4. *One* eye is made to revolve directly *inwards*, by the action of its Internal Rectus, whilst *the other* is turned *outwards* by the action of its External Rectus.—5. *One* eye is made to revolve *upwards* and *inwards*, by the conjoint action of the Superior and Internal

* The Author has been informed by his friend Mr. Bowman, that he has met with two cases of double vision, in which the defect was not experienced when the head was held erect or turned upon its vertical axis, but only when it was inclined to the one shoulder or the other. Such a peculiarity is readily explained on the above hypothesis, by the supposition that one or both of the Oblique muscles of one eye was paralysed, so that the normal rotation was not performed on that side.

† Some persons can effect this voluntarily to a greater extent than others; but even then, they can only accomplish it by fixing the gaze upon some object situated between the eyes; and cannot call the adductor muscles into combined action in perfect darkness, or if the lids be closed. Even those who have the least power of effecting this extreme convergence by at once directing the eyes towards a very near object, can accomplish it by looking at an object placed at a moderate distance, and gradually bringing this nearer to the nose, keeping the eyes steadily fixed upon it. The unwonted character of this movement is shown by this,—that it can only be maintained, even for a short time, by a strong effort, producing a sense of fatigue.

Recti; *the other*, *upwards* and *outwards*, by the conjoint action of the Superior and External Recti.—6. *One* eye is made to revolve *downwards* and *inwards*, by the conjoint action of the Inferior and Internal Recti; *the other*, *downwards* and *outwards*, by the conjoint action of the Inferior and External Recti.—In these movements, *two different* muscles, the External and Internal Recti, are called into action on the two sides, with or without the superior and inferior Recti; but they are so employed for the purpose of directing the axes of the eyes towards *the same* point; and although, as just noticed, we can put the two Internal Recti in action together, we cannot voluntarily cause the two External Recti to contract together, it not being possible that any object should be in such a position as to require this action for the direction of the axes of the eyes towards it.

798. The greater number of the foregoing movements may be performed unconsciously to ourselves, in obedience to a Voluntary determination to keep the direction of the eyes fixed, instead of to give motion to the eyeballs. Thus, if we gaze steadily at an object in front of us, and then depress the head forwards on its transverse axis, the eyeballs roll upwards upon their transverse axes (1) by the action of the Superior Recti, without our being aware of it; so if, whilst still maintaining the same fixed gaze, we raise the head into the vertical position and then depress it backwards, the eyeballs are rolled downwards (2) by the action of the Inferior Recti; if, under the same conditions, the head be made to rotate on its vertical axis from side to side, the eyeballs will be made to roll on their vertical axes in the contrary direction, by the External and Internal Recti (4) of the two sides respectively; so, by causing the head to move obliquely in the opposite directions, the reverse oblique movements (5 and 6) of the eyeballs are made to take-place by the continued fixation of the vision upon the same object. To these we have to add one more action, which cannot be called-forth in any other mode; namely, that rotation of the two eyes upon their antero-posterior axes, which takes-place probably by the instrumentality of the Oblique muscles, when we incline the head to one side or the other by rotating it upon its antero-posterior axis (§ 796). In all these movements, as in the preceding, the Will directs the *result;* and there is no other difference between them, than that which arises out of our consciousness of a change in the one case, and our unconsciousness in the other.—The truly Involuntary movements of the eyeballs, however, are performed under very different conditions; there being here no purposive direction or fixation of the gaze, and the muscular contractions not being determined by visual sensations, but being called-forth by nerve-force excited in some remote part. Of this we have an example in the normal revolution of both eyes upwards and inwards, which takes place in the acts of coughing, sneezing, winking, &c.; but far more remarkable illustrations are presented in those abnormal movements of the eyeballs, occurring in Convulsive diseases, in which there is neither harmony nor symmetry.

799. It has been stated to be a condition of single and distinct vision, that the *usual* axes of the eyes should be directed towards the object, in order that its picture should be thrown upon the parts of the two retinæ which are *accustomed* to act together (§ 760); but as this cannot take-place without the guidance of visual sensations, the movements of the

eyeballs are wanting in harmony, whenever the visual power has been deficient from birth. This is most remarkably the case, where the deficiency has been so complete that not even light can be distinguished; but the movements are frequently very far from being harmonious, in cases of congenital cataract, where a considerable amount of light is evidently admitted, but where no distinct image can be formed; and in such cases, the movements are most harmonious where the object is bright or luminous, and more vivid impressions are therefore made upon the retinæ. It is no objection to this doctrine to say, that persons who have *become* blind may still move their eyes in a harmonious manner; since, the habit of the association of particular movements having been once acquired, the guidance of the muscles may be effected by sensations derived from themselves, in the manner in which it takes-place in the laryngeal movements of the deaf and dumb (§ 542); and, as a matter of fact, a want of consent may often be observed where the blindness is total. The peculiar 'vacant' appearance, which may be noticed in the countenances of persons completely deprived of sight by amaurotic or other affections, which do not alter the external aspect of the eyes, seems to result from this,—that their axes are *parallel*, as if the individual were looking into distant space, instead of presenting that slight convergence which must always exist between them, when the eyes are fixed upon a definite object. This convergence, which is of course regulated by the Internal Recti, varies in degree according to the distance of the object; and it is astonishing how minute an alteration in the axes of the eyes becomes perceptible to a person observing them. For instance, A sees the eyes of B directed towards his face, but he perceives that B is *not looking* at him; he knows this by a sort of intuitive interpretation of the fact, that his face is not the point of convergence of B's eyes. But if B, who might have been previously looking at something nearer or more remote than A's face, fix his gaze upon the latter, so that the degree of the convergence of the axes is altered, without the general direction of the eyes being in the least affected, the change is at once perceived by the person so regarded; and the *eyes* of the two then *meet*.—It is an interesting confirmation of the principles here advocated, that when binocular vision cannot be obtained by directing the true axes of the eyes towards the object, as happens when an opaque spot exists upon the centre of the cornea, or an artificial pupil has been formed at the margin of the iris, there is an automatic tendency to the neutralization of the mischief, by such an action of the muscles as shall turn the *virtual* axis of the affected eye (that is, the axis in which the rays most directly enter the globe) towards the object, thus producing Strabismus, but *not* Double Vision.

800. The physiological principles which have now been stated, have an important application in the treatment of *Strabismus* by operation; a practice whose frequent want of success is due in great part to the injudicious selection of cases, and to the wrong measures pursued.—The degree in which habit accustoms parts of the retinæ that did not originally correspond, to work together harmoniously, is remarkably shown by the fact, that patients who have been long affected with Convergent Strabismus, and who see equally well with both eyes (as many do), are not troubled with double vision. On the other hand, when a person whose eyes look straight before him, is the subject of a disorder which

renders their motions in any degree irregular, he is at once affected with double vision. The same has been frequently noticed as an immediate result of the successful operation for the cure of Strabismus, where vision is good in both eyes; for although the images were previously formed on parts of the retinæ which were very far from corresponding with each other, yet no sooner is the position of the eyes rectified (so that the relation between the situation of the images is the same as it would be in a sound eye), than the patient sees double. Now in these cases the difficulty very speedily diminishes, and the patient soon learns to see single. That there is a *greater* tendency to consent between the images, however, when they are formed upon the parts of the two retinæ which normally correspond, may be freely admitted: and this seems to be a principle of some importance in determining the re-adjustment of the eyes, after the operation for Strabismus. This re-adjustment is not always immediate; for after the muscle has been freely divided, the eye often remains somewhat inverted for a few days, gradually acquiring its straight position. The Author has known one case, in which, after such a degree of temporary inversion as seemed to render the success of the operation very doubtful, eversion actually took place for a short time to a considerable extent; after which the axes became parallel, and have remained so ever since.—Another argument derivable from the results of this operation, in favour of the consensual movement being chiefly regulated by the correspondence in the seats of the impressions on the two retinæ, is, that it is much more successful in those cases in which the sight of the most displaced eye is good, than in those in which (as not unfrequently happens from long disuse) it is much impaired. In cases of the latter class, the cure is seldom complete.*

* In reference to this subject, the Author would add that he is well convinced, from repeated observation, that those Surgeons are in the right, who have maintained that, in a large proportion of cases, Strabismus is caused by an affection of *both* sets of muscles or nerves, and not of one only; and that it then requires, for its perfect cure, the division of the corresponding muscles on both sides. Cases will be frequently met with, in which this is evident, the two eyes being employed to nearly the same extent, and the patient giving to both a slight inward direction, when desired to look straight forwards. In general, however, one eye usually looks straight forwards, whilst the other is greatly inverted; and the sight of the inverted eye is frequently affected to a considerable degree by disuse; so that, when the patient voluntarily rotates it upon its proper axis, his vision with it is far from being distinct. Some Surgeons have maintained, that the inverted eye is usually the only one in fault, and consider that the division of the tendon of its Internal Rectus is sufficient for the cure. They would even divide its other tendons, if the parallelism be not restored, rather than touch the other eye. The Author is himself satisfied, however, that the restriction of the abnormal state to a single eye, is the exception, and not the rule, in all but very slight cases of Strabismus; and to this opinion he is led, both by the consideration of the mode in which strabismus first takes place, and by the results of the operations which have come under his notice. If the eyes of an infant affected with cerebral disease be watched, there will frequently be observed in them very irregular movements, the axes of the two being sometimes extremely convergent, and then very divergent. This irregularity is rarely or never seen to be confined to one eye. Now, in a large proportion of cases of Strabismus, the malady is a consequence of some cerebral affection during infancy or childhood, which we can scarcely suppose to have affected one eye only. Again, in other instances we find the Strabismus to have resulted from the constant direction of the eyes to very near objects, as in short-sighted persons; and here, too, the cause manifestly affects both.—Now it is easy to understand why one eye of the patient should *appear* to be in its natural position, whilst the other is greatly inverted. The cause of Strabismus usually affects the two eyes somewhat unequally, so that one is much more inverted than the other. We will call the least inverted eye A, and the

3. *Energy and Rapidity of Muscular Contraction.*

801. The energy of Muscular contraction is of course to be most remarkably observed, in those instances in which the continual exercise of particular parts has occasioned an increased determination of blood towards them, and in consequence a permanent increase of their bulk (§ 344 III). This has been the case for example, with persons who have gained their livelihood by exhibiting feats of strength. Much will, of course, depend on the mechanically-advantageous application of muscular power and in this manner, effects may be produced, even by persons of ordinary strength, which would not have been thought credible. In lifting a heavy weight in each hand, for example, a person who keeps his back perfectly rigid, so as to throw the pressure vertically upon the pelvis, and only uses the powerful extensors of the thigh and calf, by straightening the knees (previously somewhat flexed), and bringing the leg to a right angle with the foot, will have a great advantage over one who uses his lumbar muscles for the purpose. A still greater advantage will be gained by throwing the weight more directly upon the loins, by means of a sort of girdle, shaped so as to rest upon the top of the sacrum and the ridges of the ilia; and by pressing with the hand upon a frame, so arranged as to bring the muscles of the arms to the assistance of those of the legs. In this manner, a single Man of ordinary strength may raise a weight of 2000 lbs.; whilst few who are unaccustomed to such exertions, can lift more than 300 lbs. in the ordinary mode. A man of great natural strength, however, has been known to lift 800 lbs. with his hands; and the same individual performed several other curious feats of strength, which seem deserving of being here noticed. "1. By the strength of his fingers, he rolled up a very large and strong pewter dish. 2. He broke several short and strong pieces of tobacco-pipe, with the force of his middle-finger, having laid them on the first and third finger. 3. Having thrust-in under his garter the bowl of a strong tobacco-pipe, his legs being bent, he broke it to pieces by the tendons of his hams, without altering the bending of the knee. 4. He broke such another bowl

other B. In the ordinary acts of vision, the patient will make most use of the least inverted eye, A, because he can most readily look straight forwards or outwards with it; but to bring it into the axis, or to rotate it outwards, necessitates a still more decided inversion of B. This remains the position of things,—the patient usually looking straight forwards with A, which is the eye constantly employed for the purposes of vision,—and frequently almost burying the other eye B, the vision in which is of very little use to him, under the inner canthus. When, therefore, the tendon of the internal rectus of B is divided, the relative position of the two is not entirely rectified. Sometimes it appears to be so for a time; but the strabismus then begins to return, and it can only be checked by division of the tendon of the other eye, A; after which, the cure is generally complete and permanent. That it has not been so in many of the patients on whom operations have been performed, the Author attributes, without the slightest doubt in his own mind, to the neglect of the second operation. As just now stated, the sight of the most inverted eye is frequently very imperfect; indeed it is sometimes impaired to such an extent, that the patients speak of it as entirely useless. That this impairment results in part from disuse merely, seems very evident, from the great improvement which often succeeds the rectification of the axes. A valuable memoir by Prof. Pancoast, on the "Operation for Strabismus," founded on the results of about 1000 cases, will be found in the "Philadelphia Medical Examiner," vol. vii., and an abstract of it in the "Brit. and For. Med.-Chir. Review," July, 1852, p. 262.

between his first and second fingers, by pressing them together sideways. 5. He lifted a table six feet long, which had half a hundred weight hanging at the end of it, with his teeth, and held it in that position for a considerable time. It is true, the feet of the table rested against his knees, but as the length of the table was much greater than its height, that performance required a great strength to be exerted by the muscles of his loins, neck, and jaws. 6. He took an iron kitchen poker, about a yard long, and three inches in circumference, and holding it in his right hand, he struck it on his bare left arm between the elbow and the wrist, till he bent the poker nearly to a right angle. 7. He took such another poker, and, holding the ends of it in his hands, and the middle of it against the back of his neck, he brought both ends of it together before him; and, what was yet more difficult, he pulled it straight again."* Haller mentions an instance of a man, who could raise a weight of 300 lbs., by the action of the elevator muscles of his jaw: and that of a slender girl, affected with tetanic spasm, in whom the extensor muscles of the back, in the state of tonic contraction or opisthotonos, resisted a weight of 800 lbs., laid on the abdomen with the absurd intention of straightening the body.—It is to be recollected, that the mechanical application of the power developed by muscular contraction, to the movement of the body, is very commonly disadvantageous as regards *force;* being designed to cause the part moved to pass over a much greater space than that through which the muscle contracts. Thus the Temporal muscle is attached to the lower jaw, at about one third of the distance between the condyle and the incisors; so that a shortening of the muscle to the amount of half an inch, will draw-up the front of the jaw through an inch and a half; but a power of 900 lbs. applied by the muscle, would be required to raise 300 lbs. bearing on the incisors. In the case of the fore-arm and leg, the disproportion is much greater; the points of attachment of the muscles, by which the knee and elbow-joints are flexed and extended, being much closer to the fulcrum, in comparison with the distance of the points on which the resistance bears.

802. The rapidity of the changes of position of the component particles of muscular fibres, may, as Dr. Alison justly remarks,† be estimated, though it can hardly be conceived, from various well-known facts. The pulsations of the heart can sometimes be distinctly numbered in children, at more than 200 in the minute; and as each contraction of the ventricles occupies only half the time of the whole pulsation, it must be accomplished in 1-400th of a minute, or 3-20ths of a second. Again, it is certain that, by the movements of the tongue and other organs of speech, 1500 letters can be distinctly pronounced by some persons in a minute: every one of these must require a separate contraction of muscular fibres, and the production and cessation of each of the sounds, implies that each separate contraction must be followed by a relaxation of equal length; each contraction, therefore, must have been effected in 1-3000th part of a minute, or in 1-50th of a second. Haller calculated that, in the limbs of a dog at full speed, muscular contractions must take place in less than the 1-200th of a second, for many minutes at least in succession.—All these instances, however, are thrown into the shade, by those

* "Desaguliers' Philosophy," vol. ii.

† "Cyclopædia of Anatomy and Physiology," Art. 'Contractility.'

which may be drawn from the class of Insects. The rapidity of the vibrations of the wings may be estimated from the musical tone which they produce; it being easily ascertained by experiments, what number of vibrations are required to produce any note in the scale (§ 787). From these data, it appears to be the necessary result, that the wings of many Insects strike the air *many hundred* or even *many thousand* times in every *second*.—The minute precision with which the degree of muscular contraction can be adapted to the designed effect, is in no instance more remarkable than in the Glottis. The musical pitch of the tones produced by it, is regulated by the degree of tension of the *chordæ vocales*, which are possessed of a very considerable degree of elasticity (§ 805). According to the observations of Muller,* the average length of these, in the male, in a state of repose, is about 73 100ths of an inch; whilst, in the state of greatest tension it is about 93-100ths; the difference being therefore 20-100ths, or *one-fifth* of an inch: in the female glottis, the average dimensions are about 51-100ths, and 63-100ths respectively, the difference being thus about *one-eighth* of an inch. Now the natural compass of the voice, in most persons who have cultivated the vocal organ, may be stated at about two octaves, or 24 semitones. Within each semitone, a singer of ordinary capability could produce at least ten distinct intervals, so that of the total number, 240 is a very moderate estimate. There must, therefore, be at least 240 different states of tension of the Vocal Cords, every one of which is producible by the will, without any previous trial; and the *whole* variation in the length of the cords being not more than one-fifth of an inch, even in man, the variation required to pass from one interval to another, will not be more than 1-1200th of an inch. And yet this estimate is much below that, which might be truly made from the performances of a practised vocalist.†

[It has been thought by the Author, that it would be scarcely accordant with the plan of this work, and that it would add needlessly to its bulk, if he were to enter into that minute analysis of the various groups of Muscular actions concerned in standing, sitting, walking, running, swimming, &c., which some writers have thought to form an essential part of a Physiological Treatise. Such an analysis, as it appears to him, leads to no practically-important result; and the actions of individual muscles, into which these composite groups are thus resolved, must after all, be separately studied in connection with their respective attachments and directions of traction. The subject of the locomotion of Man has been particularly investigated by the Profrs. Weber, whose work on the "Mechanik der menslich Gehewerzenge," (Gottingen, 1836) has been translated in Jourdan's "Encyclopédie Anatomique," tom ii. See also the Art. 'Motion' by Mr. J. Bishop, in "Cyclop. of Anat. and Physiol.," vol. iii.]

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* "Elements of Physiology," Baly's translation, p. 1018.

† It is said that the celebrated Madame Mara was able to sound 100 different intervals between each tone. The compass of her voice was at least three octaves, or 21 tones; so that the total number of intervals was 2100, all comprised within an extreme variation of one-eighth of an inch; so that it might be said that she was able to determine the contractions of her vocal muscles to nearly the *seventeen-thousandth* of an inch.

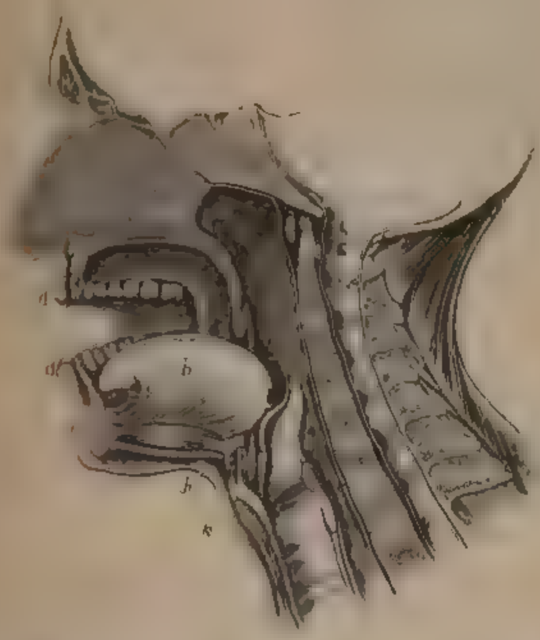
CHAPTER XIV.

OF THE VOICE AND SPEECH.

1.—*Of the Larynx, and its Actions.*

803. THE sounds produced by the organ of Voice constitute the most important means of communication between Man and his fellows (§ 613), and the power of Speech has, therefore, a primary influence, as well on

Fig. 166.



Median Section of *Mouth*, *Nose*, *Pharynx*, and *Larynx*:—*a*, septum of nose; below it, section of hard palate; *b*, tongue; *c*, section of velum pendulum palati; *d d*, lips; *u*, uvula; *e*, anterior arch or pillar of fauces; *i*, posterior arch; *t*, tonsil; *p*, pharynx; *h*, hyoid bone; *k*, thyroid cartilage; *n*, cricoid cartilage; *s*, epiglottis; *v*, glottis; 1, posterior opening of nares; 3, isthmus faucium; 4, superior opening of larynx; 5, passage into Œsophagus; 6, mouth of right Eustachian tube.

his physical condition, as on the development of his mental faculties. It is necessary to bear in mind, that Vocal sounds, and Speech or articulate Language, are two things entirely different; and that the former may be

produced in great perfection, where there is no capability for the latter. Hence we might at once infer, that the instrument for the production of vocal sounds is distinct from that by which these sounds are modified into articulate speech; and this we easily discover to be the case, the voice being unquestionably produced in the *larynx*, whilst the modifications of it by which language is formed, are effected for the most part in the *oral cavity*.—The structure and functions of the former, then, first claim our attention.

804. It will be remembered that the Trachea is surmounted by a stout cartilaginous annulus, termed the *Cricoid* cartilage (Figs. 107, 108, A B,

Fig. 107.

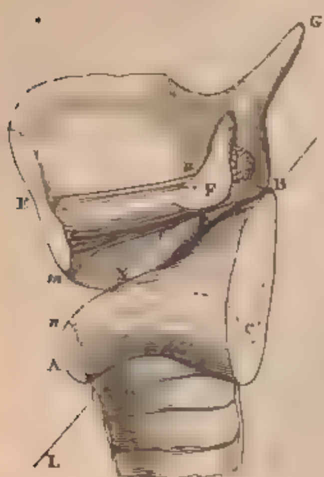
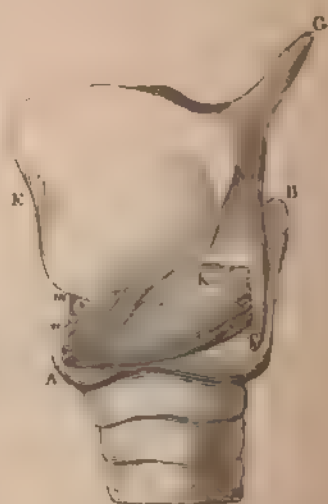


Fig. 108.



External and Sectional views of the *Larynx*,—A N B, the cricoid cartilage; E C G, the thyroid cartilage; G, its upper horn; C, its lower horn, where it is articulated with the cricoid; F, the arytenoid cartilage; E F, the vocal ligament; A E, crico-thyroideus muscle; F e G, thyro-arytenoideus muscle; X F, crico-arytenoideus lateralis; K, transverse section of arytenoideus transversus; *m n*, space between thyroid and cricoid; B L, projection of axis of articulation of arytenoid with thyroid.

Fig. 109, *r u* X *w*); which serves as a foundation for the superjacent mechanism. This is embraced (as it were) by the *Thyroid* (Figs. 107, 108, E C G, Fig. 109, G E H), which is articulated to its sides by the lower horns (Figs. 107, 108, C), round the extremities of which it may be regarded as turning, as on a pivot. In this manner, the lower front border of the Thyroid cartilage, which is ordinarily separated by a small interval (Figs. 107, 108, *m n*) from the upper margin of the Cricoid, may be made to approach it or to recede from it; as any one may easily ascertain, by placing his finger against the little depression which may be readily felt externally, and observing its changes of size, whilst a range of different tones is sounded; for it will then be noticed that, the higher the note, the more the two cartilages are made to approximate, whilst they separate

in proportion to the depth of the tones.* Upon the upper surface of the back of the Cricoid, are seated the two small *Arytenoid* cartilages (Figs. 107, 109, F F): these are fixed in one direction by a bundle of strong ligaments, which tie them to the back of the cricoid; but they have some power of moving in other directions, upon a kind of articulating surface. The direction of the surface, and the mode in which these cartilages are otherwise attached, cause their movement to be a sort of rotation in a plane which is nearly horizontal but partly downwards; so that their vertical planes may be made to separate from each other, and at the same time to assume a slanting position. This change of place will be better understood, when the action of the muscles is described. To the summit of the Arytenoid cartilages are attached the *chordæ vocales* or Vocal Ligaments (Fig. 107, E F, Fig. 109, T V), which stretch across to the front of the Thyroid cartilage, and it is upon the condition and relative situation of these ligaments, that their action depends. It is evident that they may be rendered more or less tense, by the movement of the Thyroid cartilage just described; being tightened by the depression of its front upon the Cricoid cartilage, and slackened by its elevation. On the other hand, they may be brought into more or less close apposition, by the movement of the Arytenoid cartilages; being made to approximate nearly, or to recede in such a manner as to cause the rima glottidis to assume the form of a narrow V, by the revolution of these cartilages.—We shall now inquire into the actions of the muscles upon the several parts of this apparatus; and first into those of the larynx alone.

Fig. 109

Bird's-eye view of *Larynx* from above. G, H, H, the thyroid cartilage, embracing the ring of the cricoid R, N, X, N, and turning upon the axis x z, which passes through the lower horns, (Fig. 107); N V, N V, the arytenoid cartilages, connected by the arytenoideus transversus, T V, T V, the vocal ligaments; N X, the right crico-arytenoideus lateralis (the left being removed); V k f, the left thyro-arytenoideus (the right being removed); N l, N l, the crico-arytenoidei postici; n, n, the crico-arytenoid ligaments.

805. The depression of the front of the Thyroid cartilage, and the consequent *tension* of the Vocal Ligaments, is occasioned by the conjoint action of the *Crico-thyroidei* (Fig. 108, A K) on both sides; and the chief antagonists to these are the *Thyro-arytenoidei* (Fig. 107, F m, Fig. 109, V k f), which draw the front of the thyroid back towards the arytenoid cartilages, and thus *relax* the vocal ligaments. These two pairs of muscles may be regarded as the principal governors of the *pitch* of the notes, which, as we shall hereafter see, is almost entirely regulated by the tension of the ligaments; their action is assisted, however, by that of other muscles presently to be mentioned.—The arytenoid cartilages are made to diverge from each other, by means of the *Crico-arytenoidei postici* (Fig. 109, N l)

* In making this observation, it is necessary to put out of view the general movement of the Larynx itself, which the finger must be made to follow up and down.

of the two sides, which proceed from their outer corners, and turn somewhat round the edge of the Cricoid, to be attached to the lower part of its

Fig. 110.

Part of Fig. 109 enlarged, to show the *Direction of the Muscular Forces* which act on the Arytenoid cartilage:— N Y O, the right Arytenoid cartilage; N Y, its vocal ligament; [illegible] bundle of ligaments uniting it to Cricoid; O P, projection of its axis of articulation; [illegible] direction of the action of the Thyro-arytenoideus; N X, direction of Crico-arytenoideus lateralis; N W, direction of Crico-arytenoideus posticus; N V, direction of Arytenoideus transversus.

back; their action is to draw the outer corners backwards and downwards, so that the points to which the vocal ligaments are attached are separated from one another, and the rima glottidis is thrown *open*. This will be at once seen from the preceding diagram, in which the direction of traction of the several muscles is laid-down.—The action of these muscles is partly antagonised by that of the *Crico-arytenoidei laterales* (Fig. 109, N X), which run forwards and downwards from the outer corners of the Arytenoid cartilages, and whose contraction tends to bring their anterior points into the same straight line, depressing them at the same time, so as thus to *close* the glottis. These muscles are assisted by the *Arytenoideus transversus* (Fig. 109), which connects the posterior faces of the Arytenoid cartilages, and which, by its contraction, draws them together. By the conjoint action, therefore, of the Crico-arytenoidei laterales and of the Arytenoideus transversus, the whole of the adjacent faces of the Arytenoid cartilages will be approximated, and the points to which the vocal ligaments are attached will be depressed. —But if the Arytenoideus be put in action in conjunction with the Crico-arytenoidei postici, the tendency of the latter to separate the Arytenoid cartilages being antagonised by the former, its backward action only will be exerted, and thus it may be caused to aid the Crico-thyroidei in rendering tense the vocal ligaments. This action will be further assisted by the *Sterno-thyroidei*, which tend to depress the Thyroid cartilage, by pulling from a fixed point below;* and the *Thyro-hyoidei* will be

* These are not usually reckoned among the principal muscles concerned in regulating the voice; but that they are so, any one may convince himself by placing his finger just above the sternum, whilst he is sounding high notes; a strong feeling of muscular tension is then at once perceived.

the antagonist of these, when they act from a fixed point above, the Os Hyoides being secured by the opposing contraction of several other muscles. The respective actions of these muscles will be best comprehended by the following Table.

Govern the pitch of the notes.

Antagonists	CRICO-THYROIDEI STERNO-THYROIDEI	Depress the front of the Thyroid cartilage on the Cricoid, and *stretch* the vocal ligaments, assisted by the Arytenoideus and Crico-arytenoidei postici
	THYRO-ARYTENOIDEI THYRO-HYOIDEI	Elevate the front of the Thyroid cartilage, and draw it towards the Arytenoids, *relaxing* the vocal ligaments

Govern the Aperture of the Glottis.

Antagonists	CRICO-ARYTENOIDEI POSTICI	*Open* the Glottis
	CRICO-ARYTENOIDEI LATERALES ARYTENOIDEUS TRANSVERSUS	Press together the inner edges of the Arytenoid cartilages, and *close* the Glottis

808. The muscles which stretch or relax the Vocal ligaments, are entirely concerned in the production of Voice; those which govern the aperture of the Glottis have important functions in connection with the Respiratory actions in general, and stand as guards (so to speak) at the entrance to the lungs. These separate actions are easily made evident. In the ordinary condition of rest, it seems probable that the Arytenoid cartilages are considerably separated from each other; so as to cause a wide opening to intervene between their inner faces, and between the vocal ligaments, through which the air freely passes; and the vocal ligaments are at the same time in a state of complete relaxation. We can close the aperture of the Glottis by an exertion of the will, during either inspiration or expiration, and its closure by an automatic impulse forms part of the acts of Coughing and Sneezing (§ 306), besides giving-rise to those more prolonged impediments to the ingress and egress of air, which have been already noticed as resulting from disordered states of the Nervous system (§§ 720, 724). With these actions, the muscles which regulate the tension of the vocal ligaments have nothing to do, and we have seen that they are performed by the instrumentality of the Pneumogastric or proper Respiratory nerve (§§ 303, 304). A slight examination of the recent Larynx is sufficient to make it evident, that, when once the borders of the rima glottidis are brought-together by muscular action, the effect of strong aerial pressure on either side (whether produced by an expulsory blast from below, or by a strong inspiratory effort, occasioning a partial vacuum below, and consequently an increased pressure above), will be to force them into closer apposition. In order to produce a Vocal sound, it is not sufficient to put the ligaments into a state of tension; they must also be brought nearer to each other. That the aperture of the glottis is greatly narrowed during the production of sounds, is easily made evident to one's-self, by comparing the time occupied by an ordinary expiration, with that required for the passage of the same quantity of air during the sustenance of a vocal tone. Further, the size of the

aperture is made to vary in accordance with the note which is being produced; of this, too, any one may convince himself, by comparing the times during which he can hold-out a low and a high note, from which it will appear, that the aperture of the glottis is so much narrowed in producing a high note, as to permit a far less rapid passage of air than is allowed when a low one is sounded. This adjustment of the aperture to the tension of the vocal ligaments, is a necessary condition for the production of a clear and definite tone. It further appears that, in the narrowing of the glottis which is requisite to bring the vocal ligaments into the necessary approximation, the upper points of the Arytenoid cartilages are caused to approximate, not only by being made to rotate horizontally towards each other, but also by a degree of elevation; so that the inner faces of the vocal ligaments are brought into parallelism with each other,—a condition which may be experimentally shown to be necessary for their being thrown into sonorous vibration (§ 810). The muscular movements concerned in the act of vocalization, appear to be called-forth by the instrumentality of the fibres of the Spinal Accessory nerve which are contained in the Pneumogastric (§ 498).

807. We have now to inquire what is the operation of the Vocal Ligaments in the production of sounds; and in order to comprehend this, it is necessary to advert to the conditions under which tones are produced by instruments of various descriptions having some analogy with the Larynx. These are chiefly of three kinds; strings, flute-pipes, and reeds or tongues.—The Vocal Ligaments were long ago compared by Ferrein to vibrating *strings;* and at first sight there might seem a considerable analogy, the sounds which both produce being elevated by increased tension. This resemblance disappears, however, on more accurate comparison; for it may be easily ascertained by experiment, that no string so short as the vocal ligaments could give a clear tone, at all to be compared in depth with that of the lowest notes of the human voice; and also, that the scale of changes produced by increased tension is fundamentally different. When strings of the same length but of different tensions are made the subject of comparison, it is found that the number of vibrations is in proportion to the square-roots of the extending forces. Thus, if a string extended by a given weight produce a certain note, a string extended by four times that weight will give a note in which the vibrations are twice as rapid, and this will be the octave of the other. If nine times the original weight be employed, the vibrations will be three times as rapid as those of the fundamental note, producing the twelfth above it. Now by fixing the larynx in such a manner that the vocal ligaments can be extended by a known weight, Muller has ascertained that the sounds produced by a variation of the extending force do not follow the same ratio, and therefore the condition of these ligaments cannot be simply that of vibrating cords. Further, although a cord of a certain length, which is adapted to give-out a clear and distinct note, equal in depth to the lowest of the human voice, may be made by increased tension to produce all the superior notes (which, in stringed instruments, are ordinarily obtained by shortening the strings), it does not follow that a short string, which, with moderate tension, naturally produces a high note, should

be able, by a diminution of the tension, to give-out a deep one; for, although this might be theoretically possible, yet it cannot be accomplished in practice, since the vibrations become irregular on account of the diminished elasticity.* These considerations are in themselves sufficient to destroy the supposed analogy, and to prove that the Chordæ Vocales cannot be reduced to the same category with vibrating strings.

808. The next kind of instrument with which some analogy might be suspected, is the *flute-pipe*, in which the sound is produced by the vibration of an elastic column of air contained in the tube; and the pitch of the note is determined almost entirely by the length of the column, although slightly modified by its diameter, and by the nature of the embouchure or mouth from which it issues. This is exemplified in the German Flute, and in the English Flute or Flageolet, in both of which instruments, the acting length of the pipe is determined by the interval between the embouchure and the nearest of the side-apertures; by opening or closing which, therefore, a modification of the tone is produced. In the Organ, of which the greater number of pipes are constructed upon this plan, there is a distinct pipe for every note; and their length increases in a regular scale. It is, in fact, with flute-pipes as with strings,—that a diminution in length causes an increase in the number of vibrations, in a simply-inverse proportion; so that of two pipes, one being half the length of the other, the shorter will give a tone which is the octave above the other, the vibrations of its column of air being twice as rapid. Now there is nothing in the form or dimensions of the column of air between the larynx and the mouth, which can be conceived to render it at all capable of such vibrations as are required to produce the tones of the Human voice, though there is some doubt, whether it be not the agent in the musical tones of certain Birds. The length that would be required in an open pipe to give the lowest G of the ordinary bass voice, is nearly six feet; and the conditions necessary to produce the higher notes from it, are by no means those which we find to exist in the process of modulating the human voice.

809. We now come to the third class of instruments, in which sound is produced by the vibration of *reeds* or *tongues*; these may either possess elasticity in themselves, or be made elastic by tension. The 'free' reeds of the Accordion, Concertina, Seraphine, Harmonium, &c., are examples of instruments of this character, in which the lamina vibrates in a sort of frame that allows the air to pass-out on all sides of it through a narrow channel, thus increasing the strength of the blast: whilst in the Hautboy, Bassoon, &c., and in the Organ-pipes of similar construction, the reed covers an aperture at the side of one end of a pipe. In the former kind, the sound is produced by the vibration of the tongue alone, and is regulated entirely by its length and elasticity; whilst in the latter, its pitch is dependent upon this, conjointly with the length of the tube, the column of air contained in which is thrown into simultaneous vibration. Some interesting researches on the effect

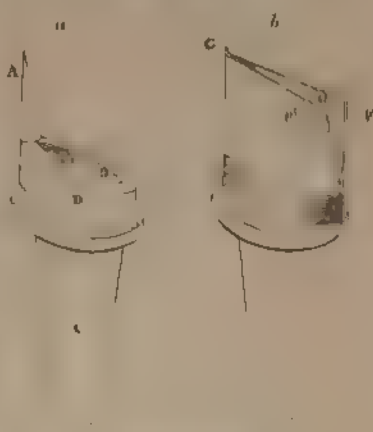
* Thus it would be impossible to produce good Bass notes on the strings of a Violin, by diminishing their tension; the length afforded by the Violoncello or Double Bass is requisite.

produced on the pitch of a sound given by a reed through the union of it with a tube, have been made by M. W. Weber; and, as they are important in furnishing data by which the real nature of the vocal organ may be determined, their chief results will be here given.—I. The pitch of a reed may be lowered, but cannot be raised, by joining it to a tube. II. The sinking of the pitch of the reed thus produced, is at the utmost not more than an octave. III. The fundamental note of the reed thus lowered, may be raised again to its original pitch, by a further lengthening of the tube; whilst by a further increase it is again lowered. IV. The length of tube necessary to lower the pitch of the instrument to any given point, depends on the relation which exists between the frequency of the vibrations of the tongue of the reed, and those of the column of air in the tube, each taken separately. -From these data, and from those of the preceding paragraph, it follows that, if a wind-instrument can, by the prolongation of its tube, be made to yield tones of any depth in proportion to the length of the tube, it must be regarded as a flute-pipe; whilst if its pitch can only be lowered an octave or less (the embouchure remaining the same) by lengthening the tube, we may be certain that it is a reed instrument. The latter proves to be the case in regard to the Larynx.

810. It is evident from the foregoing considerations, that the action of the Larynx has more analogy to that of *reed* instruments, than it has to that either of vibrating *strings*, or of *flute pipes;* and though there would seem, at first sight, to be a marked difference in character between the vocal ligaments and the tongue of any reed instrument, this difference is really by no means considerable. In a reed, elasticity is a property of the tongue itself, when fixed at one end, the other vibrating freely; but by a membranous lamina, fixed in the same manner, no tone would be produced. If such a lamina, however, be made elastic by a moderate degree of tension, and be fixed in such a manner as to be advantageously acted-on by a current of air, it will give a distinct tone. It is observed by Muller, that membranous tongues made elastic by tension, may have either of three different forms. I. That of a band extended by a cord, and included between two firm plates, so that there is a cleft for the passage of air on each side of the tongue. II. The elastic membrane may be stretched over the half or any portion of the end of a short tube, the other part being occupied by a solid plate, between which and the elastic membrane a narrow fissure is left. III. Two elastic membranes may be extended across the mouth of a short tube, each covering a portion of the opening, and having a chink left open between them.—This last is evidently the form most allied to the Human Glottis; but it may be made to approximate still more closely, by prolonging the membranes in a direction parallel to that of the current of air, so that not merely their edges, but their whole planes, shall be thrown into vibration. Upon this principle, a kind of *artificial glottis* has been constructed by Mr Willis, the conditions of action and the effects of which, are so nearly allied to that of the real instrument, that the similar character of the two can scarcely be doubted. The following is his description of it. "Let a wooden pipe be prepared of the form of Fig. 111 *a*, having a foot, c, like that of an organ pipe, and an upper opening, long and

narrow, as at B, with a point, A, rising at one end of it. If a piece of leather, or still better, of sheet India-rubber, be doubled round this point, and secured by being bound round the pipe at D with strong thread, as in Fig 111 *b*, it will give us an artificial glottis with its upper edges G H, which may be made to vibrate or not, at pleasure, by inclining the planes of the edges. A couple of pieces of cork, E F, may be glued to the corners, to make them more manageable. From this machine, various notes may be obtained, by stretching the edges in the direction of their length G H, the notes rising in pitch with the increased tension, although the length of the vibrating edge is increased. It is true that a scale of notes equal in extent to that of the human voice, cannot be obtained from edges of leather, but this scale is much greater in India rubber than in leather; and the elasticity of them both is so much inferior to that of the vocal ligaments, that we may readily infer that the greater scale of the latter is due to its greater elastic powers." By other experimenters, the tissue forming the middle coat of the arteries has been used for this purpose, in the moist state, with great success, with this, the tissue of the vocal ligament is nearly identical. It is worthy of remark that, in all such experiments, it is found that the two membranes may be thrown into vibration, when inclined *towards* each other in various degrees, or even when they are in parallel planes, and their edges only approximate; but that the least inclination *from* each other (which is the position the vocal ligaments have during the ordinary state of the glottis, § 806), completely prevents any sonorous vibrations from being produced.

Fig. 111.



Artificial Glottis

811 The pitch of the notes produced by membranous tongues, may be affected in several ways. Thus, an increase in the strength of the blast, which has little influence on metallic reeds, raises *their* pitch very considerably; and in this manner the note of a membranous reed may be raised by semitones, to as much as a fifth above the fundamental. The addition of a pipe has nearly the same effect on their pitch, as on that of metallic reeds; but it cannot easily be determined with the same precision. Several different notes may be produced with a pipe of the same length; but there is a certain length of the column of air, which is the one best adapted for each tone. It has been recently ascertained, moreover, that the length of the pipe prefixed to the reed has a considerable influence on its tone, rendering it deeper in proportion as it is prolonged, down to nearly the octave of the fundamental note; but the pitch then suddenly rises again, as in the case of the tube placed beyond the reed. The researches of Muller, however, have not succeeded in

establishing any very definite relation between the lengths of the two tubes, in regard to their influence on the pitch of the reed placed between them.

812. From the foregoing statements it appears, that the true theory of the Voice may now be considered as well established, in regard to this essential particular,—that the sound is the result of the vibrations of the vocal ligaments, which take place according to the same laws with those of metallic or other elastic tongues: and that the pitch of the notes is chiefly governed by the tension of these laminæ.* With respect, however, to the mode and degree in which these tones are modified by the shape of the air-passages, both above and below the larynx, by the force of the blast, and by other concurrent circumstances, little is certainly known; but no doubt can be felt that these modifications are of great importance, when we observe the great amount of muscular action which takes place consentaneously with the production of vocal tones, and which seems designed to alter the length and tension of the various parts of the *vocal tube*, so that they may vibrate synchronously with the *vocal cords*. Thus, during the ascent of the voice from the deeper to the higher notes of the scale, we find the whole larynx undergoing an elevation towards the base of the cranium, the thyroid cartilage being drawn-up within the os-hyoides, so as even to press on the epiglottis; at the same time, the small space between the thyroid and cricoid cartilages, or crico-thyroid chink, is closed by the depression of the front of the former upon the latter (§ 804); the velum palati is depressed and curved forwards; and the tonsils approach one another. The reverse of all these movements takes place during the descent of the voice.—A very important adjunct to the production of the higher notes has been pointed-out by Muller, as being afforded by the modification in the space included between the two sides of the thyroid cartilage, which is effected by the thyro-arytenoidei. He had experimentally ascertained that the introduction of a hollow plug into the upper end of the pipe beneath his artificial larynx (and therefore just below the reed), by diminishing its aperture, produced a considerable elevation of the tone. The action may be imitated in the human larynx, when made the subject of experiment, by compressing the thyroid cartilage laterally; and in this manner, the natural voice can be made to extend through a range that could otherwise be only reached by a falsetto.—The influence of the prefixed and superadded tubes, in modifying the tones produced by the Human larynx, has been found by Prof. Muller not to be at all comparable to that which they exercised over the artificial larynx; the reason of which difference does not seem very apparent. It appears, however, that there is a certain

* It is considered, however, by Mr. Bishop ("Cyclop. of Anat. and Physiol.," vol. iv. p. 1486), that the vocal apparatus combines the properties of a stretched cord, a membranous pipe with a column of air vibrating in it, and a reed, and is the perfect type, of which these instruments are only imperfect adaptations. The Author is unable, however, to deduce from Mr. Bishop's previous statements the grounds upon which he makes this assertion, and does not understand how any instrument *can* combine the actions of *cords* and of *tongues*, the laws of whose vibration are so different. That the column of air in the air-passages is thrown into vibration consentaneously with the production of sound by the vocal cords, and intensifies that sound by reciprocation, can scarcely be doubted: but the reasons previously given appear to the Author sufficient to disprove the notion, that this vibration is at all more essential to the production of the vocal tone, than it is in the reed pipe of an organ.

length of the prefixed tube—as there is a certain distance of the vibrating laminae, and a certain length or form of the tube above,—which is most favourable to the production of each note; and the downward movement of the whole vocal organ, which takes-place when we are sounding deep notes, and its rise during the elevation of the tones, have been supposed to answer the purpose of making this adjustment in the length of the trachea; but this requires the supposition, that the real length of the trachea is shortened whilst it appears extended,—for which there seems no foundation. It is considered by Mr Wheatstone, that the column of air in the trachea may divide itself into 'harmonic lengths,' and may produce a *reciprocation* of the tone given by the vocal ligaments (§ 778); and in this manner he considers that the falsetto notes are to be explained. It may be added, that the partial closing of the epiglottis seems to assist in the production of deep notes, just as the partial covering of the top of a short pipe fixed to a reed will lower its tone; and that something of this kind takes place during natural vocalisation, would appear from the retraction and depression of the tongue, which accompany the lowering of the front of the head, when the very lowest notes are being sounded. The experiments of Savart have shown, that a cavity which only responds to a shrill note, when its walls are firm and dry, may be made to afford a great variety of lower tones, when its walls are moistened and relaxed in various degrees. This observation may probably be applied also to the trachea.

813. The *falsetto* is a peculiar modification of the voice, differing from the 'chest voice,' not merely in the higher pitch of its notes, but also in their quality; its tones being less reedy, and more like the 'harmonic notes' of stringed and wind instruments. In some individuals, the chest-voice passes by imperceptible gradations into the falsetto, whilst in others the transition is abrupt; and some persons can sound the same notes in the two different registers, these notes forming the upper part of the scale of the chest-voice, and the lower part of the falsetto.* —With regard to the theory of the production of the falsetto voice, there has been considerable difference of opinion amongst Physiologists, and it cannot be regarded as fully determined. By Magendie and Mayo it was maintained that these tones are produced by the vibration of the vocal cords along only half their length, the rima glottidis being partly closed; and this explanation is consistent with the fact, that a far smaller quantity of air is required for sustaining a falsetto note, than for a note of the ordinary register, even though they should be of the same pitch. By Muller, again, it is asserted that in the production of the falsetto notes, merely the thin border of the glottis vibrates, so that the fissure remains distinctly visible; whilst, in the production of the ordinary vocal tones, the whole breadth of the vocal ligaments is thrown into strong vibrations, which traverse a wider space, so that a confused motion is

* Thus a gentleman of the Author's acquaintance has a bass voice of a harsh reedy character, ranging from the D below the bass cleff to the D above it (two octaves), whilst his falsetto, which is remarkable for its clearness and smoothness, ranges from the A on the highest line of the bass cleff to the E in the highest space of the treble cleff. Hence there are five notes common to the two registers, and the entire voice ranges through more than three octaves; but from want of a gradual passage from one to the other, this gentleman can only sing bass parts with his chest-voice, or alto parts with his falsetto, the tenor scale extending above the range of one, and below that of the other.

seen in the lips of the glottis, rendering its fissure indefinite. It is not impossible that both these doctrines may be correct, and that, in the production of falsetto notes, the vocal ligaments are in contact with each other for part of their length, their thin edges only being in vibration in the remainder. It has been pointed-out by Mr. Bishop (loc. cit.), that at the moment of transition from the 'chest-voice' to the 'falsetto-voice,' the crico-thyroid chink, which was closed during the production of the highest note of the former, suddenly opens on the production of the lowest note of the latter, thus indicating that the Vocal Cords are *relaxed* in the passage from the one to the other, as must be the case, if, for the production of the same note, they be only put in vibration along a part of their length; so that it would not seem improbable that the cause of those differences in the mode of transition which have been already noticed, lies in the difference in the proportional amount of the vocal cords, which is thus thrown-out of use by the partial approximation of the two lips of the rima glottidis. It is further remarked by Mr. Bishop, that, in the passage from the chest- to the falsetto-voice, the larynx descends from its previously-elevated position, and gradually rises again with the ascending scale of falsetto notes; and he mentions a case of *double falsetto*, in which a third register existed, and in which the relaxation of the Vocal cords and the descent of the larynx were observed at its commencement, as at the commencement of the second or ordinary falsetto register.—An entirely different theory of the falsetto has been given, however, by MM. Pétrequin and Diday,* who consider that the falsetto notes are not produced by the vibration of the vocal cords, but are really 'flute-notes,' formed by the vibrations of the column of air to which the rima-glottidis then serves as the embouchure. This view harmonizes well with some of the phenomena of the falsetto-voice; but it is open to the objections already stated in regard to the flute-theory generally. It may be added that some have attempted to show, that the falsetto depends upon a peculiar action of the parts *above* the larynx; but for this doctrine there is no foundation whatever.

814. The various muscular actions which are employed in the production and regulation of the Voice, are called-forth by an impulse which has been shown (§§ 542, 547) to be really *automatic* in its operation, and to be completely under the influence of guiding sensations, although usually originating in a Volitional determination, or giving expression to Emotions or simply to Ideas. This, however, has been proved to be also true of *all* Volitional movements; so that the production of vocal tones constitutes no real exception. It may be safely affirmed, that the simple utterance of sounds is in itself an Instinctive action; although the combination of these, whether into music or into articulate language, is a matter of acquirement, which is much more readily made by some individuals than by others. No definite tone can be produced by a Voluntary effort, unless that tone be present to the consciousness during an interval—however momentary,—either as immediately produced by an act of Sensation, recalled by an act of Conception, or anticipated by an effort of the Imagination. When thus present, the Will can enable the muscles to assume the condition requisite to produce it; but under no other circum-

* "Gazette Medicale," 1844.

stances does this happen, except through the particular mode of discipline by which the congenitally-deaf may be trained to speak. Such persons are debarred from learning the use of Voice in the ordinary manner; for the necessary guidance cannot be afforded, either through sensations of the present or conceptions of the past, and the imagination is entirely destitute of power to suggest that which has been in no shape experienced. But they may be taught to acquire an imperfect speech, by causing them to imitate particular muscular movements, which they may be made to see, being guided in the imitation of those movements, in the first place by watching their own performance of them in a looking-glass, and afterwards by attending to the muscular sensations which accompany them. Many instances, indeed, are on record, in which persons entirely deaf were enabled to carry-on a conversation in the regular way; judging of what was said by the movements of the lips and tongue, which they had learned to connect with particular syllables; and regulating their own voices in reply, by their voluntary power, guided in its exercise by their muscular sensations.*

[In the foregoing account of the Physiology of Voice, the Author has been chiefly guided by the excellent paper by Mr Willis in the "Transactions of the Cambridge Philosophical Society," vol. iv; and by the elaborate investigations of Müller and his coadjutors, as detailed in the Fourth Book of his Physiology. Mr J. Bishop's article 'Voice,' in the Fourth Volume of the "Cyclopædia of Anatomy and Physiology," may also be advantageously consulted.]

2.—*Of Articulate Sounds.*

815. The larynx, as now described, is capable of producing those *tones* of which Voice fundamentally consists, and the sequence of which becomes Music: but *Speech* consists in the modification of the laryngeal tones, by other organs intervening between the Glottis and the Os externum, so as to produce those *articulate sounds* of which language is formed. It cannot be questioned that Music has its language; and that it is susceptible of expressing Emotional states of the mind (among those, at least, who have been accustomed to associate these with its varied modes) to even a higher degree than articulate speech (§ 610). But it is incapable of addressing the Intellect, by conveying definite ideas of objects, properties, actions, &c., in any other way than by a kind of imitation, which may be compared to the signs used in hieroglyphic writing. These ideas it is the peculiar province of Articulate Language to convey (§ 613); and we find that the vocal organ is adapted to form a large number of simple sounds, which may be readily combined into groups, forming words. The number of combinations which can be thus produced, is so inexhaustible, that every language has its own peculiar series, no difficulty being found in forming new ones to express new ideas. There is considerable diversity in different languages, even with regard to the use of the simplest of these combinations; some of them are more easy of formation than others, and these accordingly enter into the composition of all languages; whilst of the more difficult ones, some are employed in one language, some in another,—no one language possessing them all. Without entering into any detailed account of the mechanism required to produce each of these

* See Dr. Johnstone "On Sensation," p. 128

simple sounds, a few general considerations will be offered in regard to the classification of them; and the peculiar defect of articulation, termed *Stammering*, will be briefly treated-of.

816. Vocal sounds are divided into Vowels and Consonants; and the distinctive characters of these are usually considered to be, that the Vowels are produced by the Voice alone, whilst the sound of the Consonant is formed by some kind of interruption to the voice, so that they cannot be properly expressed, unless conjoined with a vowel. The distinction may be more correctly laid-down, however, in this manner:—the Vowel sounds are continuous tones, modified by the form of the aperture through which they pass-out; whilst in sounding Consonants, the breath suffers a more or less complete interruption, in its passage through parts anterior to the larynx. Hence the really simple Vowel-sounds are capable of prolongation during any time that the breath can sustain them; this is not the case, however, with the real Diphthongal sounds (of which it will presently appear that the English *i* is one); whilst it is true of some Consonants. It seems to have been forgotten by many of those who have written upon this subject, that the laryngeal voice is not essential to the formation of either vowels or consonants; for all may be sounded in a whisper. It is very evident, therefore, that the larynx is not primarily concerned in their production; and this has been fully established by the following experiment. A flexible tube was introduced by M. Deleau through his nostril into the pharynx, and air was impelled by it into the fauces; then, closing the larynx, he threw the fauces into the different positions requisite for producing articulate sounds, when the air impelled through the tube became an audible whisper. The experiment was repeated, with this variation,—that the laryngeal sounds were allowed to pass into the fauces; and each articulated letter was then heard double, in a proper voice and in a whisper.

817. That the Vowels are produced by simple modifications in the form of the external passages, is easily proved, both by observation and by imitative experiment. When the mouth is opened wide, the tongue depressed, and the velum palati elevated, so as to give the freest possible exit to the voice, the vowel *a* in its broadest form (as in *ah*) is sounded.* On the other hand, if the oral aperture be contracted, the tongue being still depressed, the sound *oo* (the continental *u*) is produced. If attention be paid to the state of the buccal cavity, during the pronunciation of the different vowel-sounds, it will be found to undergo a great variety of modifications, arising from varieties of position of the tongue, the cheeks, the lips, and velum palati. The position of the tongue is, indeed, one of the primary conditions of the variation of the sound; for it may be easily ascertained that, by peculiar inflexions of this organ, a great diversity of vowel-sounds may be produced, the other parts remaining the same. Still there is a certain position of all the parts, which is most favourable to the formation of each of these sounds; but this could not be expressed without a lengthened description. The following table, slightly altered from that of Kempelen, expresses the relative dimensions of the buccal *cavity* and of the oral *orifice*, for some of the principal of these; the

* This sound of the vowel *a* is scarcely used in our language, though very common in most of the Continental tongues; the nearest approach to it in English is the *a* in *far* but this is a very perceptible modification, tending towards *au*.

number 5 expressing the largest size, and the others in like proportion —

Vowel.	*Sound*	*Size of oral opening.*	*Size of buccal cavity.*
a	as in *ah*	5	5
a	as in *name*	4	2
e	as in *theme*	3	1
o	as in *cold*	2	4
oo	as in *cool*	1	5

These are the sounds of the five vowels, *a*, *e*, *i*, *o*, *u*, in most Continental languages; and it cannot but be admitted, that the arrangement is a much more natural one than that of our own vowel series. The English *a* has three distinct sounds capable of prolongation,*—the true broad *a* of *ah*, slightly modified in *far*, the *a* of *fate*, corresponding to the *e* of French; and the *a* of *fall*, which should be really represented by *au*. This last is a simple sound, though commonly reckoned as a diphthong. In Kempelen's scale, the oral orifice required to produce it would be about 3, and the size of the buccal cavity 4.† On the other hand, the sound of the English *i* cannot, like that of a true vowel, be prolonged *ad libitum;* it is in fact a sort of diphthong, resulting from the transition from a peculiar indefinite murmur to the sound of *e*, which takes its place when we attempt to continue it. The sound *oy* or *oi*, as in *oil*, is a good example of the true diphthong, being produced by the transition from *au* to *e*. In the same manner, the diphthong *ou*, which is the same with *ow* in owl, is produced in the rapid transition from the broad *a* of *ah*, to the *oo* of cool. — Much discussion has taken place as to the true character of *y*, when it commences a word, as in yet, yawl, &c.; some having maintained that it is a consonant (for the very unsatisfactory reason, that we are in the habit of employing *a* rather than *an*, when we desire to prefix the indefinite article to such words), whilst others regard it as a peculiar vowel. A slight attention to the position of the vocal organs during its pronunciation, makes it very clear, that its sound in such words really corresponds with that of the long (English) *e;* the pronunciation of the word yawl being the same as that of ēaul, when the first sound is not prolonged, but rapidly transformed into the second. The sound of the letter *w*, moreover, is really of the vowel character, being formed in the rapid transition from *oo* to the succeeding vowel, thus *wall* might be spelt *ŏŏall*. Many similar difficulties might be removed, and the conformity between spoken and written language might be greatly increased (so as to render far more easy the acquirement of the former from the latter), by due attention to the state of the vocal organs in the production of the simple sounds.

818. It is not very difficult to produce a tolerably good artificial imitation of the Vowel-sounds. This was accomplished by Kempelen, by means of an India-rubber ball, with an orifice at each end, of which the lower

* The *short* vowel sounds, as *a* in fat, *e* in met, *o* in pot, &c., are not capable of prolongation.

† The mode of making a determination of this kind may here be given, for the sake of example. If the broad *a* be sounded, the mouth and fauces being opened wide, and we contract the oral orifice by degrees, at the same time slightly elevating the point of the tongue, we gradually come to the sound of *au*, by still further contracting the orifice, and again depressing the tongue, we form *oo*. On the other hand, in sounding *e*, the tongue is raised nearly to the roof of the mouth; if it be depressed, without the position of the lips being altered, *au* is given.

one was attached to a reed: by modifying the form of the ball, the different vowels could be sounded during the action of the reed. He also employed a short funnel like tube, and obtained the different sounds by covering its wide opening to a greater or less extent. This last experiment has been repeated by Mr. Willis; who has also found that the vowel sounds might be imitated, by drawing-out a long straight tube from the reed. In this experiment he arrived at a curious result:—with a tube of a certain length, the series of vowels, *i, e, a, o, u,* was obtained by gradually drawing it out; but, if the length was increased to a certain point, a further gradual increase would produce the same sequence in an inverted order, *u, o, a, e, i,* a still further increase would produce a return to the first scale, and so on. When the pitch of the reed was high, and the pipe short, it was found that the vowels *o* and *u* could not be distinctly formed, —the proper tone being injured by the elongation of the pipe necessary to produce them, and this, Mr. Willis remarks, is exactly the case in the Human voice, most singers being unable to pronounce *u* and *o* upon their highest notes.

819. The most natural primary division of the Consonants, is into those which require a total stoppage of the breath at the moment previous to their being pronounced, and which, therefore, cannot be prolonged, and those in pronouncing which the interruption is partial, and which can, like the vowel sounds, be prolonged *ad libitum.* The former have received the designation of *explosive,* and the latter of *continuous.* —In pronouncing the *explosive* consonants, the posterior nares are completely closed, so that the exit of air through the nose is altogether prevented, and the current may be checked in the mouth in three ways,—by the approximation of the lips,—by the approximation of the point of the tongue to the front of the palate,—and by the approximation of the middle of the tongue to the arch of the palate. In the first of these modes, we pronounce the letters *b* and *p;* in the second, *d* and *t;* in the third, the hard *g* and *k.* The difference between *b, d,* and *g,* on the one hand, and *p, t,* and *k,** on the other, seems to depend on this; that in the former group the approximating surfaces are larger, and the breath is sent through them more strongly at the moment of opening, than in the latter. The *continuous* consonants may be again subdivided, according to the degree of freedom with which the air is allowed to make its exit, and the compression which it consequently experiences. 1. The first class includes those, in which no passage of air takes-place through the nose, and in which the parts of the mouth that produce the sound are nearly approximated together, so that the compression is considerable. This is the case with *v* and *f,* which are produced by approximating the upper incisors to the lower lip; and which stand in nearly the same relation to each other, as that which exists between *d* and *t,* or *b* and *p.* The sibilant sounds, *z,* and *s,* also stand in a similar relation to each other, they are produced by the passage of air between the point of the tongue and the front of the palate, the teeth being at the same time nearly closed. The simple sound *sh* is formed, by narrowing the channel between the dorsum of the tongue and the palate; the former being elevated towards the latter, through a considerable part of its length. If, in sounding *s,* we raise the point of

* For the sake of proper comparison, this letter should be sounded not as *kay* but *ky*

the tongue a very little, so as to touch the palate, the sound of *t* is evolved, and in the same manner *d* is produced from *z*. This class also includes the *th*, which, being a perfectly simple sound, ought to be expressed by a single letter, as in Greek, instead of by two, whose combination does not really produce anything like it. For producing this sound, the point of the tongue is applied to the back of the incisors, or to the front of the palate, as in sounding *t*,* but, whilst there is complete contact of the tip, the air is allowed to pass-out around it.—II. In the second class of continuous consonants, including the letters *m*, *n*, *l*, and *r*, the nostrils are not closed; and the air thus undergoes very little compression, even though the passage of air through the oral cavity is almost or completely checked. In pronouncing *m* and *n*, the breath passes through the nose alone; and the difference of the sound of these two letters must be due to the variation in the form of the cavity of the mouth, which acts by resonance. The letter *m* is a labial, like *b*; but in the former the nasal passage is open, the mouth remaining closed, whilst in the latter the nose is entirely closed, and the sound is formed at the moment of opening the mouth; hence the passage from *m* to *b* is made with great facility. The same correspondence exists between *n* and *t*, or *n* and *g* (the particular part of the tongue approximated to the palate not being of much consequence in the pronunciation of *n*); and hence it is that the transition from *n* to *t*, or from *n* to *g*, is so easy that the combinations *nt* and *ng* are found abundantly in most languages. The sound of *l* is produced by bringing the tip of the tongue into contact with the palate, and allowing the air to escape around it, at the same time that a vocal tone is generated in the larynx; it differs, therefore, from *th* in the position at which the obstruction is interposed, as well as in the slight degree of compression of the air which it involves. The sound of the letter *r* depends on an absolute vibration of the point of the tongue, in a narrow current of air forced between the tongue itself and the palate.—III. The sounds of the third class are scarcely to be termed consonants, since they are merely *aspirations* caused by an increased force of breath. These are *h*, and the guttural *ch*† of most foreign languages (the Greek χ). The first is a simple aspiration, the second an aspiration modified by the elevation of the tongue, causing a slight obstruction to the passage of air, and an increased resonance in the back of the mouth. This sound would become either *g* or *k*, if the tongue, whilst it is being produced, were carried up to touch the palate.‡

820. These distinctions come to be of much importance, when we apply ourselves to the treatment of defects of articulation. Great as is the number of muscles employed in the production of definite vocal sounds, the number is much greater for those of articulate language; and the varieties of combination which we are continually forming unconsciously to ourselves, would not be suspected, without a minute analysis of the separate actions. Thus, when we utter the explosive sounds, we check the passage of air through the posterior nares, in the very act of

* Hence it is easy to understand the substitution of *t* or *d*, for the English *th*, by foreigners.

† The English *ch* is merely a combination of *t* with *sh*, thus *chime* might be spelt *tshime*.

‡ The general classification proposed by Dr. M. Hall has been here adopted, with some modification as to the details.

articulating the letter; and yet this important movement commonly passes unobserved.—We must regard the power of forming the several articulate sounds which have been adverted to, and their simple combinations, as so far resulting from intuition, that it can in general be more readily acquired by early practice than other actions of the same complexity; but we find that among different Races of Men, there exist tendencies to the production of different sounds, which, though doubtless influenced in great degree by early habit (since we find that children, when first learning to speak, form their habits of vocalization in great degree in accordance with the examples amidst which they are placed), are certainly also dependent in part upon congenital constitution, as we often see in the case of children among ourselves, who grow up with certain peculiarities of pronunciation, not thus derived from imitation, of which they do not seem able to divest themselves.

821. It is in the want of power to *combine* the different muscular actions concerned in vocalization, that the defect termed *Stammering* essentially consists. Many theories regarding the nature of this impediment have been proposed; and there can be little doubt that it may be attributed to a great variety of exciting causes. A disordered action of the nervous centres, must, however, be regarded as the proximate cause, though this may be (to use the language of Dr. M. Hall) either of *centric* or of *excentric* origin,—that is, it may result from a morbid condition of the ganglionic centre, or from an abnormal impression conveyed through its afferent nerves. When of centric origin (and this is probably the most general case), the phenomena of Stammering and Chorea have a close analogy to each other (§ 712); in fact, stammering is frequently one of the modes in which the disordered condition of the nervous system in Chorea manifests itself.—It is in the pronunciation of the Consonants of the *explosive* class, that the stammerer experiences the greatest difficulty. The total interruption to the breath which they occasion, frequently becomes quite spasmodic;* and the whole frame is thrown into the most distressing semi-convulsive movement, until relieved by expiration. In the pronunciation of the *continuous* Consonants of the first class, the stammerer usually prolongs them, by a spasmodic continuance of the same action; and there is, in consequence, an impeded, but not a suspended respiration. The same is the case with the *l* and *r* in the second class. In pronouncing the *m* and *n*, on the other hand, as well as the aspirates and vowels, it is sometimes observed that the stammerer prolongs the sound, by a full and exhausting expiration. In all these cases, then, it seems as if the muscular sense, resulting from each particular combination of actions, became the stimulus to the involuntary prolongation of that state. It is possible that the defect may result, in some instances, from malformation of the parts about the fauces, producing an abnormal stimulus of this kind in some particular positions of the organ; and such cases *may be* really benefited by an operation for the removal of these parts. But the effect of such an operation is certainly exerted in most cases through the *mind* of the patient; the expectation of benefit from it tending to improve his command over the muscles of vocalization, which

* By Dr. Arnott this interruption is represented as taking place in the larynx; that such is not usually the case, the Author believes that a little attention to the ordinary phenomena of voice will satisfactorily prove.

Emotional excitement always impairs; and the improvement is usually proportional to the confidence which he has been led to feel in the result. The slightest disturbance of the feelings is sufficient in most Stammerers to induce a complete perturbation of the vocal powers; the very fear that stammering will occur, particularly under circumstances which render it peculiarly annoying, is often sufficient to bring it on in a predisposed subject; and the tendency to consensual imitation sometimes occasions stammering, in individuals (especially children) who never show the slightest tendency to it except when they witness the difficulty in others.

822. The method proposed by Dr. Arnott for the prevention of Stammering, consists in the connection of all the words by a vocal intonation, in such a manner, that there shall never be an entire stoppage of the breath. It is justly remarked by Muller, however, that although this plan may afford some benefit, it cannot do everything; since the main impediment occurs in the middle of words themselves. One important remedial means, on which too much stress cannot be laid, is to study carefully the mechanism of the articulation of the difficult letters, and to practise their pronunciation repeatedly, slowly, and analytically. The patient would at first do well to practise sentences from which the explosive consonants are omitted; his chief difficulty, arising from the spasmodic suspension of the expiratory movement, being thus avoided. Having mastered these, he may pass-on to others, in which the difficult letters are sparingly introduced; and may finally accustom himself to the use of ordinary language. One of the chief points to be aimed-at, is to make the patient feel that he *has* command over his muscles of articulation (§ 625); and this is best done, by gradually leading him from that which he finds he *can* do, to that which he fears he *cannot*. The fact that stammering people are able to *sing* their words better than to *speak* them, has been usually explained on the supposition that, in singing, the glottis is kept open, so that there is less liability to spasmodic action; if, however, as here maintained, the spasmodic action is not in the larynx, but in the velum palati and the muscles of articulation, the difference must be due to the direction of the attention rather to the muscles of the larynx than to those of the mouth.—One of the most important objects to be aimed-at in the treatment of stammering, consists in the prevention of all Emotional disturbance in connection with the act of Speech; and this requires the exercise of the Voluntary power over the direction of the thoughts, in the following modes.—1. To *reduce* mental emotion, by a daily, hourly, habit of abstracting the mind from the subject of stammering, both while speaking, and at other times. 2. To *avoid exciting* mental emotion by attempting unnecessarily to read or speak, when the individual is conscious that he shall not be able to perform these actions without great distress. 3. To *elude* mental emotion, by taking advantage of any little artifice to escape from stammering, so long as the artifice continues to be a successful one.—Much may frequently be done, also, by constitutional treatment, adapted to improve the general vigour of the nervous system.*

* See on the subject of "Stammering and its Treatment," a useful pamphlet under this title, by Bacc. Med. Oxon., 1850; and Mr. Bishop's treatise "On Articulate Sounds, and on the Causes and Cure of Impediments of Speech."

CHAPTER XV.

OF THE INFLUENCE OF THE NERVOUS SYSTEM ON THE ORGANIC FUNCTIONS.

823. Of the modes in which the Nervous System influences the Organic Functions, a great part have been already considered; for it has been shown to be concerned in providing the mechanical conditions, either immediate or remote, under which alone these functions can be performed; so that, when its activity ceases, they cannot be much longer maintained. But the influence of the Nervous System is not alone exerted upon the motor or contractile tissues of the body; for there is good evidence that it has a direct operation upon the molecular changes which constitute the functions of Nutrition, Secretion, &c.; and this view may be admitted to its fullest extent, without our being thereby led to regard the processes in question as *dependent* upon Nervous agency,—a doctrine for which there seems no valid foundation (Chap. II., Sect. 2). Throughout the Animal body, it may be observed that, the more Vegetative the nature of any function, the less is it under the influence of the Nervous System, save where that influence is required to bring it into harmony with other functions (§ 41), sometimes by exciting, sometimes by checking, and sometimes by otherwise modifying them, very much in the way that a rider guides and controls the movements of his horse.—It is evident that this influence must be principally exerted through the *Sympathetic* or *Visceral* system of nerves, since a large proportion of the organs on which it operates are supplied by no other; and hence this apparatus has been commonly designated the 'Nervous system of *organic* life,' as distinguishing it from the Cerebro-spinal system, which is the 'Nervous system of *animal* life.' There is, however, no such parallelism between them, as this designation would imply; for whilst the operations of the Cerebro-spinal system *essentially constitute* the Animal life of the individual, those of the Sympathetic cannot be fairly said to do more than *control* and *direct* those of Nutrition and Secretion.—We shall now enquire into the structure and relations of the Sympathetic System; and shall then examine the nature of the actions which there seems reason to attribute to it.

824. *Sympathetic Nervous System.*—That collection of scattered but mutually-connected ganglia and nerves, of which this apparatus is made up, may be ranged under the following groups:—1. The isolated ganglia and nerves in immediate connection with the Viscera, which seem to be the chief centres of the system; these form three principal plexuses, the *Cardiac*, the *Solar*, and the *Hypogastric*. 2. The double chain of *Prevertebral* ganglia, with connecting cords, which lies in front of the Vertebral column, and which communicates on the one hand with the Spinal nerves, and on the other with the before-named plexuses. Under this head we should probably rank the minute Cranial ganglia, which are

situated in the neighbourhood of the Organs of Sense, and in immediate connection with the branches of the Fifth pair that proceed to them; these are the *ophthalmic, otic, spheno-palatine*, and *submaxillary* ganglia. 3. The *ganglia on the posterior roots* of the Spinal nerves; under which head we are probably to rank not only the *Gasserian* ganglion of the Fifth pair, but also the ganglia near the roots of the Pneumogastric and Glosso-pharyngeal nerves.—The trunks of the Sympathetic are made-up of different orders of fibres; some of these having their central termination in the vesicular matter of the Sympathetic ganglia themselves, whilst others are derived from the Cerebro-spinal system. The former, which are all of the 'gelatinous' kind,* are most abundant in the great Visceral plexuses; but they may be traced from the prevertebral ganglia into the Spinal nerves, part of them proceeding to the ganglia on their posterior roots (whence fibres are given-off that mingle with their spinal fibres), whilst another part enter the anterior roots and mingle with *their* fibres. On the other hand, the latter, which are of the 'tubular' kind, are derived by the same cords of communication (these being commonly termed the 'roots' of the Sympathetic, but being really commissural bands that bring the two systems into connection) from both roots of the Spinal nerves, and pass through the prevertebral ganglia into the Sympathetic system, without undergoing any ostensible change. Thus it appears that the Cerebro-spinal and Sympathetic systems *interpenetrate* one another; each having its own series of ganglionic centres, and of trunks connected with them; but each system transmitting its fibres into the trunks of the other, so as to be peripherically distributed with their ramifications.

825. The distribution of the principal trunks and branches of the Sympathetic system may be concisely stated as follows. -1. Those of the *Cardiac* plexus proceed chiefly to the Heart and great blood-vessels, whence they are continued, with reinforcements derived-from other subdivisions, and with multitudes of minute ganglia in their course, along the ramifications of the Vascular system throughout the body, embracing them as ivy embraces the trunk and branches of a tree. Those of the *Solar* plexus are transmitted in part to the muscular walls of the Alimentary canal, from the stomach to the lower end of the colon; in part to the principal arterial branches given-off from the aorta, and with them to the liver, pancreas, spleen, and kidneys, as also to the testes of the male and the ovaries of the female. Those of the *Hypogastric* plexus supply the muscular walls of the pelvic viscera, the bladder, urethra, vagina of the female, and rectum, besides sending branches to the bloodvessels themselves. —2. The branches of the *Prevertebral* ganglia of the trunk for the most part contribute to form the plexuses just described. Those of the neck, however, furnish a large supply to the carotid artery, round which they form a plexus, and also give-off branches which inosculate with those of the Pneumogastric to form the pharyngeal and laryngeal plexuses; and those of the upper part of the thorax give-off branches which inosculate with those of the Pneumogastric to form the pulmonary plexus. Of the *ophthalmic* ganglion (§ 492), the branches are

* It must be carefully borne in mind, that, although the proper Sympathetic fibres are all 'gelatinous,' yet that the Cerebro-Spinal system contains 'gelatinous' fibres of its own, which are very abundant in some parts. (See PRINC. OF GEN. PHYS.)

distributed, not merely to the iris, whose radiating fibres are made to contract through their instrumentality, as already explained (§ 757), but also to the vascular apparatus of the eyeball, and especially to the ciliary processes, which seem to possess a sort of erectile character. The *otic* ganglion, which communicates with the third division of the Fifth pair, and with the Glosso-pharyngeal, may be considered, from the distribution of most of its branches to the tensor tympani and circumflexus palati muscles, as ministering to the exercise of the sense of Hearing, in somewhat the same mode that the ophthalmic ganglion seems to do to that of vision (§ 781). The Spheno-palatine ganglion (Fig. 96, *f*), whose connections are with the Fifth and the Facial nerves, seems in like manner to minister, by the distribution of its branches on the mucous membrane of the nasal cavity and the palate, to the senses of Smell and Taste. Of the Submaxillary ganglion, which also is chiefly connected with the Fifth and the Facial nerves, the branches proceed almost entirely to the Submaxillary gland.—3. The fibres which arise from the ganglia on the posterior roots of the Spinal nerves (if really belonging to the Sympathetic system) must be distributed along with the branches proceeding from the trunks which they help to form, as must also a part of those fibres which are sent from the proper Sympathetic ganglia into the roots of the same nerves, a large part of them, however, being distributed upon the blood-vessels of the Spinal Cord itself.

826. If, then, it be enquired what inferences we are entitled to draw respecting the functions of the Sympathetic system of nerves, from our knowledge of its Anatomical distribution, we are at once justified in replying, that a large proportion of the Muscular apparatus which directly ministers to the Organic functions,—that, namely, which surrounds the alimentary canal from the stomach downwards, with the gland-ducts which open into it,—that, also, which forms the walls of the bladder and uterus, of the ureters and fallopian tubes,—and that, too, which governs the diameter of the blood vessels,—*receives no other nervous supply*, and, consequently, that of whatever motor influence these parts may receive from Mental states or from excitation not applied to themselves, this system of nerves must be the channel. The same may be said, too, in regard to that greater portion of the Glandular apparatus, which is exclusively supplied by the Sympathetic nerve, and chiefly by the plexuses that embrace its blood-vessels, since any such alterations in its rate of activity, or in the character of its products, as depend upon conditions of Mind, can be brought-about through no other instrumentality.—It is not a little remarkable, however, that those portions of the Muscular apparatus of Organic life, which most obviously exhibit in their action the influence of the Nervous system, both in their respondence to emotional states, and in their 'sympathy' with disturbance in other functions,—namely the Heart and the Stomach,—derive a considerable part of their nervous supply directly from the Cerebro-spinal system. And it is still more significant, that most of those Glands whose function is occasional, and whose states of activity are most obviously influenced by affections of the Mind, are specially supplied by Cerebro-spinal nerves, in addition to the Sympathetic plexuses which they receive on the walls of their blood vessels: thus, the Lachrymal and Salivary glands are supplied with branches of the Fifth and Facial nerves; the Mammary glands by

branches of the Intercostals; and the Gastric glandulæ by the Pneumogastric. It cannot but be deemed highly probable, then, from this circumstance alone, that the influence of mental states upon the function of Secretion may be exerted through the nerves of the Cerebro-spinal system, as well as through those of the Sympathetic.

827. It must be in virtue of the connections of the Sympathetic with the Cerebro-spinal system, that the parts which are solely supplied with nerves from the former, are capable of transmitting sensory impressions to the Sensorium. It is true that, under ordinary circumstances, these parts are insensible; that is, impressions made upon them do not travel onwards through the Spinal Cord to the Encephalon: but their sensibility is acutely manifested in morbid states, in which the impressions seem to be propagated further than usual, in virtue of their greater potency. That it is the office of the ganglia on the roots of the Spinal nerves to "cut off sensation," that is, to prevent the further transmission of sensory impressions, is an old doctrine; and there seems much reason to believe that this may be effected by the free communication between one fibre and another, which is established through the vesicular substance of a ganglion, so that the whole force of ordinary impressions on the nerve fibres is lost in diffusion among the rest of their contents. The same principle seems to apply to the motor fibres; for there are cases which show that when fibres obviously belonging to Cerebro-spinal nerves pass through Sympathetic ganglia, they do not so rapidly or so surely transmit motor impulses, as when they have no such relation to ganglia.*

828. Although it is not easy to obtain definite evidence of the influence of the Sympathetic system on *Muscular Contraction*, since this influence is extinguished within a short time after death, yet it has been established by the elaborate researches of Prof. Valentin and others (§§ 86, 240, 258), that contractions of the various muscular parts supplied by the three great Visceral plexuses may be excited by irritation applied to their nerves and ganglia. But Prof. V. has further shown, that the same effects may be produced by irritating either the Prevertebral ganglia, or the cords of communication with the Spinal nerves which have been sometimes called the 'roots' of the Sympathetic, or the roots of the Spinal nerves themselves. It results from his inquiries, that, although any particular division of the Sympathetic nerve must be regarded as extremely complex in its relations, deriving its motor fibres from many different sources, the ultimate distribution of these fibres is sufficiently simple, so that each organ is definitely supplied from a certain part of the Cerebro-spinal axis. But the fibres proceeding from the roots of the Cerebro-spinal nerves do not pass into the *nearest* organs, being transmitted through three or more of the prevertebral ganglia of the Sympathetic, before reaching their ultimate destination; thus the motor fibres of the cardiac plexus are principally derived from the cervical portion of the Spinal Cord, those of the solar plexus from the thoracic region, and those of the hypogastric plexus from the dorsal region. So, again, we have seen that the dilatation of the Pupil, which immediately depends on the instrumentality of the Sympathetic nerve, is called forth also by irritation of the roots of the Spinal nerves in the cervical region (§ 757).

* See Messrs. Kirkes and Paget's "Handbook of Physiology," p. 471.

829. It can only be through the Nervous System, that the Muscular apparatus of Organic life is acted-upon by states of Mind. Although no exertion of the *Will* can produce any effect upon any part of it, yet there are various organs whose muscular walls are influenced on the one hand by Emotional states, and on the other by the state of Expectant Attention. The Heart sympathizes so much with the emotions, that the language of almost all civilized nations refers to it as the *seat* of the 'feelings' (§§ 238, 239), but we have as yet no certain evidence, whether this influence is transmitted through the Sympathetic or through the Pneumogastric nerve. The former seems the more probable channel, when we bear in mind that it can be through the Sympathetic alone that those alterations in the diameter of the blood-vessels take-place, which give-rise to the *blush* of modesty or shame, or to the pallor which alternates with this in many states of mental agitation.* So, again, the influence of Emotional states is strikingly manifested in the production of the peculiar turgescence of the Erectile tissues (§ 282); and here we have a striking example of the utter powerlessness of the Will, in the well-known fact, that no amount of sexual *desire* will produce erection, if the mind be possessed with any feeling of doubt or apprehension as to the existence of the sexual *ability*. The muscular walls of the Alimentary canal seem frequently to be excited to increased action by agitating emotions, but it may be doubted how far this is a primary effect of the mental state, or how far it is consequent upon the influence of that state upon the Secretions poured into the canal (§ 832).—The influence of the state of *expectant attention*, as of the emotions, is strongly manifested in the case of the Heart; the action of which, as Sir H. Holland has remarked, "is often quickened or otherwise disturbed by the mere centering the consciousness upon it, without any emotion or anxiety. On occasions where its beats are audible, observation will give proof of this, or the physician can very often infer it while feeling the pulse; and where there is liability to irregular pulsation, such action is seemingly brought-on, or increased, by the effort of attention, even though no obvious emotion be present."† There can be no doubt that the movements of the lower part of the Alimentary Canal are capable of being affected in a similar manner, since we may frequently trace the rapid descent of the fæcal mass into the rectum, when we expect to be shortly able to discharge it; and it is in great part in this mode, that *habit* operates, in producing a readiness for defecation at particular times, and that bread pills and other suppositious purgatives unload the bowels.‡

* The pallor of extreme fear or terror is probably due rather to a state tending to Syncope, arising from a partial failure of the Heart's action.

† "Chapters on Mental Physiology," p. 16.

‡ The Author may mention the two following cases, which have fallen within his own knowledge, as curious illustrations of the influence of mental states upon the movements of the alimentary canal. The first of these occurred in the person of a literary man of a somewhat hypochondriacal temperament, who had been troubled with continual costiveness, for which he had been accustomed to take an aperient pill daily. Finding that this ceased to have its usual effect, and being fearful of increasing his regular dose, he applied for advice to a practitioner, who, having had former experience of what Mental agency alone would do, determined to try its effect in this instance. Seating his patient before him, with the abdomen uncovered, he desired him to fix his attention intently upon his abdominal sensations, and assured him that in a short time he was quite certain that he would begin to feel a movement in his bowels, which would end in a copious evacuation

830. No experimental evidence has yet been obtained, that the *proper fibres of the Sympathetic System* have any power of exciting muscular contraction, or that its ganglia can serve as centres of reflex action to the organs which they supply; on the contrary, it is quite certain that the ganglia in the posterior roots of the Spinal nerves have no such endowment. And as all the facts which have been supposed to indicate the existence of such a power, may be otherwise explained in accordance with our fundamental doctrine (§§ 86-87, 241-243), there seems to be no ground whatever for the assumption of its possession by these parts of the apparatus.—If, then, the *sensori-motor* endowments of the Sympathetic trunks be restricted to those fibres which are really Cerebro-spinal in their origin or termination, it remains to inquire what are the functions of those *true* Sympathetic fibres, whose vesicular centres lie in the ganglia of the Sympathetic system. Upon this point we can only surmise; but there appears strong ground for the conclusion, that the office of these fibres is to produce a direct influence upon the *chemico-vital* processes concerned in the Organic functions of nutrition, secretion, &c.; an influence which, although not essential to the performance of each separate act, may yet be required to harmonize them all together, and to bring them into connection with mental states.—That the Nervous system does exert such an agency, will be presently shown; and reasons have already been assigned, for regarding the Sympathetic fibres as, in certain cases, its only possible channel.

831. Turning, now, to the Cerebro-spinal system of nerves, we find that the exercise of a powerful influence by the Pneumogastric nerves, over the secretion of Gastric fluid, seems to have been conclusively established by the experimental researches formerly referred-to (§§ 101, 102); these at the same time no less clearly proving the fact, that the Secreting process is essentially independent of nervous influence, which exerts nothing more than a *regulative* control over it (§ 103).* The recent experiments of Ludwig, made with a view to determine the influence of

He himself did nothing but look steadily at his patient, with an air of great determination and confidence, and point his finger at the abdomen, moving it along the arch of the colon, and as it were in the course of the convolutions of the small intestines, so as to aid the patient in fixing his attention upon them. In a short time the expected movements were felt, and a copious evacuation soon followed; and for some time afterwards, the bowels continued to act freely without medicine. In the other case, a Lecturer at a public Institution was seized with a strong impulse to defecation during his lecture, and was greatly inconvenienced by the effort necessary to restrain it. Before every subsequent lecture in the same place, the same impulse returned upon him, notwithstanding that he might have previously unloaded his bowels elsewhere. In this case, there was obviously a state of apprehension combined with the simple anticipation; but the influence of the latter is shown by the fact, that in no other place did this individual experience the impulse in question under the like circumstances.

* It is remarkable that experimenters so accurate as Bidder and Schmidt should have even been led to doubt by the results of their experiments, whether the Pneumogastric exerts *any* influence on the Gastric secretion; since they did not find that any greater alteration took place, either in the quantity or the quality of the gastric fluid, in the case of four dogs in whose stomachs a fistulous orifice had been established, than might be fairly attributed to the shock occasioned by the severity of the operation. (See their "Verdauungssäfte und Stoffwechsel," pp. 90-97.) By Volkmann, moreover, it is affirmed that the branches of the Pneumogastric distributed on the stomach, really consist of Sympathetic filaments, which are found to constitute a larger and larger proportion of it, the farther it is examined from its point of exit from the Cranium. (See Wagner's "Handwörterbuch der Physiologie," band ii. p. 581.)

the nerve-force upon the Salivary secretion, seem to justify a like conclusion in regard to it. For he has found that section of the Facial nerve entirely suspends the secretion of the Parotid gland, save in so far as this is kept-up by the indirect action of the Fifth pair and of the Glossopharyngeal, through the stimulus afforded by the movements of mastication and deglutition; whilst the secretion of the Sub-maxillary gland is suspended by section of the Fifth and Facial, this being a direct result of the withdrawal of nervous influence, and not being merely dependent upon the absence of the stimulus afforded by the contractions of the adjacent muscles.*—It seems probable from these experiments, and from the phenomena to be presently adduced, that those secreting processes, which (from being concerned in some occasional or intermitting function, instead of forming part of that general system of Excretory actions whose uninterrupted continuance is essential to the maintenance of the normal purity of the blood, § 381) only take-place at certain times, or in consequence of definite excitants, are called into activity by the instrumentality of the nerves which supply their respective Glands. And there are various Pathological phenomena, which indicate that it is by Nervous influence that the *mucous* secretion covering the membranes is caused to be regularly formed for their protection; for, when this influence is interrupted by paralysis of the nerves, and the secretion is no longer supplied, the membrane, losing its protection, is irritated by the air or the fluids with which it may be in contact, and passes into an inflammatory condition. This is partly the explanation of the fact, now well ascertained, that the eye is liable to suppurate when the Fifth pair has been divided; and also of the frequent occurrence of disease of the mucous membrane of the bladder in paraplegia.

832. The influence of particular conditions of the Mind, in exciting, suspending, or modifying various Secretions, is a matter of daily experience. The *Lachrymal* secretion, for example, which is continually being formed to a small extent for the purpose of bathing the surface of the eye, is poured-out in great abundance under the moderate excitement of the emotions, either of joy, tenderness, or grief. It is checked, however, by violent emotions; hence in intense grief, the tears do not flow, and it is a well-known indication of moderated sorrow when the gush takes place, this very act affording a further relief (§ 624). The flow of *Saliva*, again, is stimulated by the sight, the smell, the taste, or even by the *thought* of food, especially of such as is of a savoury character. On the other hand, violent emotion may suspend the salivary secretion, as is shown by the well-known test, often resorted-to in India, for the discovery of a thief amongst the servants of a family,—that of compelling all the parties to hold a certain quantity of rice in the mouth during a few minutes,—the offender being generally distinguished by the comparative dryness of his mouthful at the end of the experiment. There is much reason to believe that the secretion of *Gastric* fluid is affected, in the same manner as that of the saliva, by the impressions made by food upon the senses; for it has been ascertained by Bidder and Schmidt (Op. cit. p. 35), that it is copiously effused into the stomachs of dogs that

* For the very ingenious experiments by which these points have been determined by Ludwig and his assistants, Becher and Rahn, see "Mittheilungen der Zurich Natur Gesellschaft," No. 50, and "Zeitschrift fur rat. Med.," N. F., band i., pp. 255-272.

have been kept fasting, when flesh or any other attractive food is placed before them. That the secretion, on the other hand, is entirely suspended by powerful mental emotion, seems almost certain, from the well-known influence which this has in dissipating the appetite for food, and in suspending the digestive process when in active operation. As a cheerful state of feeling, on the other hand, seems to be decidedly favourable to the performance of the digestive function, it probably exerts a beneficial influence, as to both quantity and quality, on the secretion of gastric fluid. Of the influence of mental states on other secretions concerned in the reduction and appropriation of the food (such as the Biliary, Pancreatic, and Intestinal fluids), neither observation nor experiment has as yet afforded any satisfactory information. It is a prevalent, and perhaps not an ill-founded opinion, that melancholy and jealousy have a tendency to increase the quantity, and to vitiate the quality, of the *Biliary* fluid. Perhaps the disorder of the organic function is more commonly the source of the former emotion, than its consequence; but it is certain that the indulgence of these feelings produces a decidedly morbific effect by disordering the digestive processes, and thus reacts upon the nervous system by impairing its healthy nutrition. A copious secretion of *fœtid gas* not unfrequently takes place in the intestinal canal, under the influence of any disturbing emotion, or the usual *fluid secretions* from its walls are similarly disordered. The tendency to Defecation which is commonly excited under such circumstances, is not, therefore, due simply to the relaxation of the sphincter ani (as commonly supposed); but is partly dependent on the unusually-stimulating character of the fæces themselves. The same may be said of the tendency to Micturition, which is experienced under similar conditions; the change in the character of the *Urine* becoming perceptible enough among many animals, in which it acquires a powerfully-disagreeable odour under the influence of fear, and thus answers the purpose which is effected in others by a peculiar secretion. The *halitus from the Lungs* is sometimes almost instantaneously affected by bad news, so as to produce fœtid breath. The *odoriferous secretion of the Skin*, which is much more powerful in some individuals than in others, is increased under the influence of certain mental emotions (as fear or bashfulness), and commonly also by sexual desire. The *Sexual* secretions themselves are strongly influenced by the condition of the mind. When it is frequently and strongly directed towards objects of passion, these secretions are increased in amount, to a degree which may cause them to be a very injurious drain on the powers of the system. On the other hand, the active employment of the mental and bodily powers on other objects, has a tendency to render less active, or even to check altogether, the processes by which they are elaborated.*

* This is a simple Physiological fact, but of high Moral application. The Author would say to those of his younger readers, who urge the wants of Nature as an excuse for the illicit gratification of the sexual passion, "Try the effects of *close mental application* to some of those ennobling pursuits to which your profession introduces you, in combination with *vigorous bodily exercise* (for the effects of which see § 560), before you assert that the appetite is unrestrainable, and act upon that assertion." Nothing tends so much to increase the desire, as the continual direction of the mind towards the objects of its gratification, especially under the favouring influence of sedentary habits; whilst nothing so effectually represses it, as the determinate exercise of the mental faculties upon other objects (§ 568), and the expenditure of nervous energy in other channels (§ 624).—There

833. No Secretion so strongly manifests the influence of the Nervous system, and especially of Emotional states, both upon its quantity and its quality, as that of the *Mammary* glands. Although the production of Milk, when once established, continually goes-on in the breasts of a nursing female, yet it is obviously accelerated in the first instance, and augmented afterwards, by the mechanical irritation of the nipple produced by the suction of the infant, and this alone (or in combination with the strong *desire* to furnish milk) has been effectual in producing the secretion in girls and old women, and even in men (§ 919). Again, in the nursing female, the secretion is often suddenly augmented by the *sight* of the infant, or even by the *thought* of him in absence, especially when associated with the idea of suckling; this gives-rise to the sudden rush of blood to the gland, which is known by nurses as the *draught*, and which may probably be attributed to a dilatation of the Mammary arteries, through the instrumentality of their Sympathetic nerves, analogous to that which takes-place in the act of blushing (§ 829).—Although we are continually witnessing indications of the powerful influence of Emotional states upon the qualities of the Mammary secretion, yet it is probable that such influence is not at all peculiar to the milk; and that we only recognize it more readily in this case, because the digestive system of the Infant is a more delicate apparatus for testing it, than any which the Chemist can devise; affording proof, by disorder of its function, of changes in the character of the secretion, which no examination of its physical properties could detect. The following remarks on this subject are abridged from Sir A. Cooper's valuable work on the Breast "The secretion of milk proceeds best in a *tranquil state of mind*, and with a cheerful temper; then the milk is regularly abundant, and agrees well with the child. On the contrary, a *fretful temper* lessens the quantity of milk, makes it thin and serous, and causes it to disturb the child's bowels, producing intestinal fever and much griping. *Fits of anger* produce a very irritating milk, followed by griping in the infant, with green stools. *Grief* has a great influence on lactation, and consequently upon the child. The loss of a near and dear relation, or a change of fortune, will often so much diminish the secretion of milk, as to render adventitious aid necessary for the support of the child. *Anxiety of mind* diminishes the quantity, and alters the quality, of the milk. The reception of a letter which leaves the mind in anxious suspense, lessens the draught, and the breast becomes empty. If the child be ill, and the mother is anxious respecting it, she complains to her medical attendant that she has little milk, and that her infant is griped and has frequent green and frothy motions. *Fear* has a powerful influence on the secretion of milk. I am informed by a medical man who practises much among the poor, that the apprehension of the brutal conduct of a drunken

seems to be something in the process of training young men for the Medical Profession, which encourages in them a laxity of thought and expression on these matters, that generally ends in a laxity of principle and of action. It might have been expected that those who are so continually witnessing the melancholy consequences of the violation of the Divine law in this particular, would be the last to break it themselves: but this is unfortunately very far from being the case. The Author regrets being obliged further to remark, that some works which have issued from the Medical press, contain much that is calculated to excite, rather than to repress, the propensity; and that the advice sometimes given by practitioners to their patients, is immoral as well as unscientific.

husband, will put a stop for a time to the secretion of milk. When this happens, the breast feels knotted and hard, flaccid from the absence of milk, and that which is secreted is highly irritating, and some time elapses before a healthy secretion returns. *Terror*, which is sudden and great fear, instantly stops this secretion." Of this, two striking instances, in which the secretion, although previously abundant, was completely arrested by this emotion, are detailed by Sir A. C. "Those passions which are generally sources of pleasure, and which, when moderately indulged, are conducive to health, will, when carried to excess, alter, and even entirely check the secretion of milk."

834. There is even evidence that the Mammary secretion may acquire an actually *poisonous* character, under the influence of violent mental excitement; for certain phenomena which might otherwise be regarded in no other light than as simple coincidences, appear to justify this inference, when interpreted by the less striking but equally decisive facts already mentioned. "A Carpenter fell into a quarrel with a Soldier billeted in his house, and was set-upon by the latter with his drawn sword. The wife of the Carpenter at first trembled from fear and terror, and then suddenly threw herself furiously between the combatants, wrested the sword from the soldier's hand, broke it in pieces, and threw it away. During the tumult, some neighbours came-in and separated the men. While in this state of strong excitement, the mother took-up her child from the cradle, where it lay playing, and in the most perfect health, never having had a moment's illness; she gave it the breast, and in so doing sealed its fate. In a few minutes the infant left-off sucking, became restless, panted, and sank dead upon its mother's bosom. The physician who was instantly called-in, found the child lying in the cradle, as if asleep, and with its features undisturbed; but all his resources were fruitless. It was irrecoverably gone."* In this interesting case, the milk must have undergone a change which gave it a powerful sedative action upon the susceptible nervous system of the infant.—The following, which occurred within the Author's own knowledge, is perhaps equally valuable to the Physiologist, as an example of the similarly-fatal influence of undue emotion of a different character; and both should serve as a salutary warning to mothers, not to indulge either in the exciting or in the depressing passions. A Lady having several children, of which none had manifested any particular tendency to cerebral disease, and of which the youngest was a healthy infant a few months old, heard of the death (from acute hydrocephalus) of the infant child of a friend residing at a distance, with whom she had been on terms of close

* Dr. Von Ammon, in his treatise "Die ersten Mutterpflichten und die erste Kindespflege," quoted in Dr. A. Combe's excellent little work on "The Management of Infancy."—Similar facts are recorded by other writers. Mr. Wardrop mentions ("Lancet," No. 516), that having removed a small tumour from behind the ear of a mother, all went well, until she fell into a violent passion; and the child, being suckled soon afterwards, died in convulsions. He was sent-for hastily to see another child in convulsions, after taking the breast of a nurse who had just been severely reprimanded; and he was informed by Sir Richard Croft, that he had seen many similar instances. Three others are recorded by Burdach ("Physiologie," § 522); in one of them, the infant was seized with convulsions on the right side and hemiplegia on the left, on sucking immediately after its mother had met with some distressing occurrence. Another case was that of a puppy, which was seized with epileptic convulsions, on sucking its mother after a fit of rage.

intimacy, and whose family had increased almost contemporaneously with her own. The circumstance naturally made a strong impression on her mind, and she dwelt upon it the more, perhaps, as she happened, at that period, to be separated from the rest of her family, and to be much alone with her babe. One morning, shortly after having nursed it, she laid the infant in its cradle, asleep and apparently in perfect health, her attention was shortly attracted to it by a noise; and, on going to the cradle, she found her infant in a convulsion, which lasted a few moments and then left it dead. Now, although the influence of the mental emotion is less unequivocally displayed in this case than in the last, it can scarcely be a matter of doubt; since it is natural that no feeling should be stronger in the mother's mind under such circumstances, than the fear that her own beloved child should be taken from her, as that of her friend had been, and it is probable that she had been particularly dwelling on it, at the time of nursing the infant on that morning.—Another instance, in which the maternal influence was less certain, but in which it was not improbably the immediate cause of the fatal termination, occurred in a family nearly related to the Author's. The mother had lost several children in early infancy, from a convulsive disorder; one infant, however, survived the usually fatal period; but whilst nursing him one morning, she had been strongly dwelling on the fear of losing him also, although he appeared a very healthy child. In a few minutes after the infant had been transferred into the arms of the nurse, and whilst she was urging her mistress to take a more cheerful view, directing her attention to his thriving appearance, he was seized with a convulsion-fit, and died almost instantly. Now although there was here unquestionably a predisposing cause, of which there is no evidence in the other cases, it can scarcely be doubted that the *exciting* cause of the fatal disorder is to be referred to the mother's anxiety. This case offers a valuable suggestion,—which, indeed, would be afforded by other considerations,—that an infant, under such circumstances should not be nursed by its mother, but by another woman of placid temperament, who has reared healthy children of her own.

835. The influence of the Nervous System upon those formative processes which constitute the function of Nutrition, is less evident than it is upon the Secretory operations; and the nature of this influence is rather to be inferred from the results of its withdrawal, than to be demonstrated in any more direct manner. These results are chiefly to be seen in the altered nutrition of parts exposed to external impressions, as the integuments generally, but particularly those of the extremities; and they may be generally expressed by the statement, that the withdrawal of nervous influence from a part, renders it less able to withstand the destructive influence of physical agencies. It has been clearly shown, however, by the careful experiments of M. Brown-Sequard (§ 501), that a great part of the injurious effects which may be observed to follow injuries of the nerves of the extremities, experimentally inflicted, are traceable to want of power on the part of the animal (consequent upon the paralysed state of the limbs) to withdraw them from irritating impressions; and must not be attributed to any deterioration of the formative operations, directly resulting from the withdrawal of nervous agency. The following case, however, which is given by Mr Paget *

* "Lectures on Surgical Pathology," vol. i. p. 43.

on the authority of Mr Hilton, seems more unequivocally to establish this connexion. "A man was at Guy's Hospital, several years ago, who, in consequence of a fracture at the lower end of the radius, repaired by an excessive quantity of new bone, suffered compression of the median nerve. He had ulceration of the thumb, and of the fore and middle fingers, which had resisted various treatment, and was cured only by so binding the wrist, that the parts on the palmar aspect being relaxed, the pressure on the nerve was removed. So long as this was done, the ulcers became and remained well; but as soon as the man was allowed to use his hand, the pressure on the nerves was removed, and the ulceration in the parts supplied by it returned." Mr. Paget (Op. cit., p. 46) also mentions the following curious case. "A lady who is subject to attacks of what are called nervous headaches, always finds next morning that some patches of her hair are white, as if powdered with starch. The change is effected in a night; and in a few days after, the hairs gradually regain their dark brownish colour."—That such effects are rather to be attributed to the loss or perversion of the influence of the Sympathetic system, than to that of the Cerebro-spinal, would appear from the fact noticed by Magendie and Longet, that destructive inflammation of the eye ensues more quickly after division of the Fifth pair *in front* of the Gasserian ganglion, than when the division is made through the roots of the nerve, between that ganglion and the brain; the Sympathetic filaments which exist largely in this nerve, being interrupted in their course to the tissues in the former case, but not in the latter. So Dr. Axmann found, that when the Spinal nerves of Frogs were divided *in front* of their Prevertebral ganglia, the nutrition of the parts supplied by them was much more injuriously affected, than it was when the section was made between these ganglia and the Spinal Cord. And this inference is further supported by the general result of observation, that atrophy of parts supplied by the Spinal nerves is much greater when the sensory (gangliated) as well as the motor roots are involved, than when the latter alone are paralysed (Paget, Op. cit. p. 48).

836. There is abundant evidence that a *sudden* and *violent* excitement of some depressing Emotion, especially Terror, may produce a severe and even a fatal disturbance of the Organic functions; with general symptoms (as Guislain* has remarked) so strongly resembling those of sedative Poisoning, as to make it highly probable that the *blood* is *directly* affected by the Emotional state, through Nervous agency; and, in fact, the emotional alteration of various secretions, just alluded to (§§ 832–834), seems much more probably attributable to some such affection of the blood, than to a primary disturbance of the secreting process itself. Although there can be no doubt that the *habitual* state of the Emotional sensibility has an important influence upon the general activity and perfection of the Nutritive processes,—as is shown by the well nourished appearance usually exhibited by those who are free from mental anxiety as well as from bodily ailment, contrasted with the "lean and hungry look" of those who are a prey to continual disquietude,—yet it is not often that we have the opportunity of observing the production of change in the nutrition of any specific part, by strong emotional excitement. In the two following cases, the correspondence of

* "Leçons Orales sur les Phrenopathies," tom. iii. pp. 165–168

the effects to their alleged causes *may* have been only casual; and a much larger collection of facts would be needed to *establish* the rationale here advanced as probable. But so many analogous though less strongly-marked phenomena are presented in the records of medical experience, and the influence of the Emotions upon the products of Secretion is so confirmatory, that there does not seem any reasonable ground for hesitation, in admitting that the same explanation may apply here also. The first of these cases, cited by Guislain (loc. cit.) from Ridard, is that of a woman who, after seeing her daughter violently beaten, was seized with great terror, and suddenly became affected with gangrenous erysipelas of the right breast. But a still more remarkable example of local disorder of nutrition, occasioned by powerful emotion, and determined as to its seat by the intense direction of the attention to a particular part of the body, is narrated by Mr. Carter.* "A lady, who was watching her little child at play, saw a heavy window-sash fall upon its hand, cutting off three of the fingers; and she was so much overcome by fright and distress, as to be unable to render it any assistance. A surgeon was speedily obtained, who, having dressed the wounds, turned himself to the mother, whom he found seated, moaning, and complaining of pain in her hand. On examination, three fingers, corresponding to those injured in the child, were discovered to be swollen and inflamed, although they had ailed nothing prior to the accident. In four-and twenty hours, incisions were made into them, and pus was evacuated; sloughs were afterwards discharged, and the wounds ultimately healed."

837. The influence of the state of *expectant attention*, in modifying the processes of Nutrition and Secretion, is not less remarkable than we have already seen it to be in the production or modification of Muscular movements (§§ 659, 829). It seems certain that the simple *direction of the consciousness* to a part, independently of emotional excitement, but with the *expectation* that some change will take place in its organic activity, is often sufficient to induce such an alteration, and would probably always do so, if the concentration of the attention were sufficient. The most satisfactory exemplification of this principle has been given by the experiments of Mr. Braid, who has succeeded in producing very decided changes in the secretions of particular organs, by the fixation of the attention upon them in the 'hypnotic' state (§ 694). Thus he brought-back an abundant flow of milk to the breast of a female who was leaving-off nursing from defect of milk, and repeated the operation upon the other breast a few days subsequently, after which the supply was abundant for nine months, and in another instance he induced the catamenial flow on several successive occasions when the usual time of its appearance had passed. It is not requisite however, to produce the state of Somnambulism for this purpose, if the attention can be sufficiently drawn to the subject in any other mode, thus Mr. Braid† has repeatedly produced the last-named result on a female who possessed considerable power of mental concentration, by inducing her to fix her thoughts upon it for ten or fifteen minutes, so as

* "On the Pathology and Treatment of Hysteria," p. 24.

† See his important Memoir on 'Hypnotic Therapeutics,' in "Edinb. Monthly Journal," July, 1853. Of the reality of this last result, the Author has had an opportunity, through Mr. Braid's kindness, of personally satisfying himself.

to bring-on a state of Abstraction.—Now the effects which are producible by this *voluntary* or determinate direction of the consciousness to the result, are doubtless no less producible by that *involuntary* fixation of the attention upon it, which is consequent upon the eager expectation of benefit from some curative method in which implicit confidence is placed. It is to such a state that we may fairly attribute most, if not all, the cures, which have been worked through what is popularly termed the 'imagination.' The cures are real facts, however they may be explained; and there is scarcely a malady in which amendment has not been produced, not merely in the estimation of the patient, but in the more trustworthy opinion of medical observers, by practices which can have had no other effect than to *direct the attention* of the sufferer to the part, and to keep alive his *confident expectation* of the cure. The 'charming-away' of warts by spells of the most vulgar kind, the imposition of royal hands for the cure of the 'evil,' the pawings and strokings of Valentine Greatrakes, the manipulations practised with the 'metallic tractors,'* the invocations of Prince Hohenlohe, *et hoc genus omne*,—not omitting the globulistic administrations of the Infinitesimal doctors, and the manipulations of the Mesmerists, of our own times, have all worked to the same end, and have all been alike successful. It is unquestionable that, in all such cases, the benefit derived is in direct proportion to the *faith* of the sufferer in the means employed: and thus we see that a couple of bread pills will produce copious purgation, and a dose of *red* poppy syrup will serve as a powerful narcotic, if the patient have entertained a sufficiently-confident expectation of such results.

838. This state of confident expectation, however, may operate for evil, no less than for good. A fixed belief that a mortal disease had seized upon the frame, or that a particular operation or system of treatment would prove unsuccessful, has been in numerous instances (there is no reason to doubt) the direct cause of a fatal result. Thus M. Ridard relates the case of a man, thirty years of age, who was affected with stone in the bladder, and who saw a patient die by his side, after being operated upon for the same complaint. The man's imagination became excited, his thoughts were constantly fixed upon the operation which he himself expected to undergo, and upon the probable death that would follow; and, in fact, without any operation at all, he died at the end of a month, affected with gangrene both of penis and scrotum. Hence also it is, that the morbid feelings of the Hypochondriac, who is constantly directing his attention to his own fancied ailments, tend to induce real disorder in the action of the organs which are supposed to be affected.—In the same category, too, may be placed those instances (to which alone any value is to be attached), wherein *a strong and persistent impression* upon the mind of a Mother, has appeared to produce a corresponding effect upon the development of the *fœtus in utero* (§ 883). In this case, the effect (if admitted to be really exerted) must be produced upon the maternal *blood*, and transmitted through it to the fœtus, since

* Dr. Haygarth of Bath (in conjunction with Mr. Richard Smith of Bristol) tested the value of 'Perkins's metallic tractors,' by substituting two pieces of wood painted in imitation of them, or even a pair of tenpenny nails disguised with sealing wax, or a couple of slate-pencils; which they found to possess all the virtues that were claimed for the real instruments.

there is no nervous communication between the parent and the offspring There is no difficulty, however, in understanding how this may occur after what has been already stated (§ 217) of the influence of minute alterations in the Blood, in determining local alterations of nutrition.

CHAPTER XVI.

OF GENERATION.

1.—*General Character of the Function.*

839. HAVING now passed in review the various operations which are concerned in maintaining the life of the *individual*, we have next to proceed to those which are destined to the perpetuation of the *race*, by the production of successive generations of similar beings. Among Plants, and the lower tribes of Animals, a multiplication of independent beings takes-place without any sexual process whatever, by a process of *gemmation* or 'budding' from the parent-stock; these 'buds,' at first entirely nourished by it, gradually become less and less dependent upon it, and at last detach themselves and maintain a separate existence. Now this process may be regarded as essentially the same with that of the multiplication of cells by *subdivision*, which is one of the most ordinary operations of growth and development; and it is peculiar in nothing else than this,—that the newly-formed structure, instead of remaining as a constituent and dependent part of the parental fabric, is capable of living independently of it, and of thus existing as a distinct individual when spontaneously or artificially detached. Among the higher tribes of Animals, as in Man, this mode of reproduction, which is merely a multiplication of the individual, and not a real Generative process, does not present itself, at least in the adult state; for in no instance do we find that a part of the body separated from the rest can develope the organs which are necessary for the sustenance of its existence, and the power which the organism possesses, of regenerating parts which it has lost by disease or accident, is restrained within very narrow limits (§ 359). But there is good ground to believe, that such a multiplication by subdivision *may* take place at that earliest period of embryonic life, at which the germ is nothing else than a mass of cells, wherein no distinction of parts has as yet manifested itself, and that the production of two complete individuals, held-together only by a connecting band, may arise from some cause which determines the subdivision of the germinal mass, at the period when its grade of development corresponds with that of the Hydra or Planaria (§ 355). And this view of the case is confirmed by the facts already stated (§ 359) in regard to the higher degree of the regenerating power during embryonic life, infancy, and childhood, as compared with that which remains after the development of the fabric has been completed.

840. The proper act of Generation in Man, as in the Animal and Vegetable Kingdoms generally (see PRINC. OF COMP. PHYS., Chap. XI.), uniformly involves the union of the contents of two peculiar cells, which may be designated as the 'sperm-cell,' and the 'germ-cell,' and, as in all higher

Animals, the 'sperm-cell' developes in its interior a self-moving *spermatozoon*, whilst the 'germ-cell' (germinal vesicle) whose contents are fertilized by the spermatozoon, is imbedded in a mass of *yolk* destined for the early nutrition of the embryo thence originating; so that this embryo, if supplied with the requisite warmth, as well as drawing into itself the aliment stored-up for it, gradually evolves itself into the likeness of its parent. There is a great difference, however, among the different tribes of Animals, as to the degree of assistance thus afforded to the embryo, the general rule being, that the higher the form which the embryo is ultimately to attain, the longer is it supported by its parent. Hence we find the embryos of most Invertebrated animals coming-forth from the egg in a condition very unlike their perfect type, and only acquiring this after a long succession of subsequent alterations, which frequently involve a complete change of form, or *metamorphosis*. In Fishes, however, the embryo, though far from having completed its embryonic development at the time of its emersion from the egg, does not differ so widely from the adult type. In Birds, there is a provision for a much more advanced development; the store of nutritious matter, or 'yolk,' being so large as to allow the whole series of changes requisite for the formation of the complete chick, to take-place before it leaves the egg. In the Mammalia, on the contrary, the quantity of yolk contained in the ovum is very small, but the embryo is only dependent upon it for the materials of its increase during the earliest stages of its evolution; for it speedily forms a special connection with the parent-structure, by means of which it is enabled to receive a continual supply of newly-prepared aliment, so as to be supported at the expense of this until far advanced in its development. Some approaches to this arrangement are met-with among certain of the lower Animals, but it is only in the higher Mammalia that it is completely carried-out; and it is only in this class, too, that we find a supplemental provision for the nutrition of the offspring after it has come forth into the world. In many of the lower tribes of Animals, the fertilization of the ova is accomplished without any sexual congress, the spermatic fluid effused by the male, coming into direct contact with the ova previously deposited by the female; but in all the higher tribes, as in Man, the spermatic fluid is conveyed into the oviducts of the female, so as to impregnate the ovum shortly after it has quitted the ovarium, or even before its final escape from it.

2.—*Action of the Male.*

841. The Spermatic fluid of the Male is secreted by glandular organs, known as *Testes*. Each of these consists of several lobules, which are separated from each other by processes of the Tunica Albuginea that pass down between them, and also by an extremely delicate membrane (described by Sir A. Cooper under the name of Tunica Vasculosa) consisting of minute ramifications of the spermatic blood-vessels united by areolar tissue. Each lobule (Fig. 112, *a a*) is composed of a mass of convoluted *tubuli seminiferi*, throughout which blood-vessels are minutely distributed. The lobules differ greatly in size, some containing one, and others many of the tubuli; the total number of the lobules is estimated at about 450 in each testis, and that of the tubuli at 840. The walls of the tubuli

are firmer than those of similar gland-canals elsewhere; for outside the basement-membrane on which the epithelium rests, they have a tolerably-firm but extensible envelope, composed of an indistinctly-fibrous connective tissue with longitudinal nuclei. Their convolutions are so arranged, that each lobule forms a sort of cone, the apex of which is directed towards the *rete testis* (*b*); and when they have reached to within a line or two of this, they cease to be convoluted, several unite together into tubes of larger diameter, and these enter the rete testis under the name of *tubuli recti*. The mode in which the tubuli terminate at the large end of the lobule, has not been clearly made-out, owing partly to the number of their anastomoses; it is probably either by cæcal endings, or by loops. The diameter of the tubuli is for the most part very uniform; in the natural condition they seem to vary from about the 1-195th to the 1-170th of an inch; but when injected with mercury, they are distended to a size nearly double the smaller of these dimensions.—The *rete testis* (*b*) consists of from seven to thirteen vessels, which run in a waving course, anastomose with each other, and again divide, being

FIG. 112.

Human Testis, injected with mercury as completely as possible:—*a*, *a*, lobules formed of seminiferous tubes; *b*, rete testis; *c*, vasa efferentia; *d*, flexures of the efferent vessels passing into the head *e*, *e*, of the epididymis; *f*, body of the epididymis; *g*, appendix; *h*, cauda; *i*, vas deferens.

FIG. 113.

Plan of the structure of the *Testis* and *Epididymis*:—*a*, *a*, seminiferous tubes; *a**, *a**, their anastomoses; the other references as in the last figure.

all connected together. The *vasa efferentia* (c), which pass to the head of the epididymis, are at first straight, but soon become convoluted (d), each forming a sort of cone, of which the apex is directed towards the rete testis, the base to the head of the epididymis (e). The number of these is stated to vary from nine to thirty, and their length to be about eight inches. The *epididymis* itself (f) consists of a very convoluted canal, the length of which is about twenty-one feet. Into its lower extremity, that is, the angle which it makes where it terminates in the vas deferens, is poured the secretion of the *vasculum aberrans* or appendix (g), which seems like a testis in miniature, closely resembling a single lobule in its structure. Its special function is unknown.

842. The fluid secreted by the Testis is mingled, during or previously to its emission, with fluid secreted by the Vesiculæ Seminales, the Prostate, Cowper's glands, &c.; and it cannot, therefore, be obtained pure, but by drawing it from the testicle itself. No accurate analysis has been made of it in the Human subject; but the following are the results of those which have been made by Frerichs * on the contents of the testes of a rabbit, a cock, and a carp. Pure Semen is a milky fluid, of a mucous consistence, and neutral or slightly-alkaline reaction. The imperfectly-developed Spermatozoa are composed of an albuminous substance, the quantity of which diminishes with their progress towards maturation, so that the perfectly-developed semen contains no albuminous compound. On the other hand, the principal component substance of the mature Spermatozoa is the same with that which is the chief constituent of the Epithelia and of the Horny tissues generally, namely, the 'binoxide of protein' of Mulder. Besides this, the spermatozoa contain about 4 per cent. of a butter-like fat, with some phosphorus in an unoxidized state, (probably combined with the fat, as in the phosphorized fats of the blood-corpuscles and of nervous matter), and about 5 per cent. of phosphate of lime. The fluid portion of the secretion is a thin solution of mucus, which, in addition to the animal matter, contains chloride of sodium, and small quantities of alkaline sulphates and phosphates. The peculiar odour which the Semen possesses, does not appear to belong to the proper spermatic fluid; but is probably derived from one or other of the secretions with which it is mingled.—The product of the secretion of each Testis is conveyed-away by a single *vas deferens* (i), which is a cylindrical canal, having, within its fibrous wall, a layer of non-striated muscular fibre, and being lined by a proper mucous membrane. The vas deferens, ascending into the abdominal cavity as a part of the spermatic cord, reaches the fundus of the bladder; and there it comes into proximity with the *Vesicula Seminalis* of its own side, with whose duct it unites, to form the *ejaculatory duct* which terminates on the *verumontanum* of the urethra. It has been commonly supposed that the *vesiculæ seminales* stand to the *vasa deferentia* in the same light that the gall-bladder stands to the hepatic duct, namely, as a receptacle into which the seminal fluid may regurgitate, and within which it may accumulate; but (as Hunter was the first to maintain) this is not the case, since the fluid that is found in them is not semen, and but rarely contains even a small admixture of seminal fluid.† Moreover, these organs are not simple

* Art. '*Semen*' in "Cyclop. of Anat. and Physiol.," vol. iv. p. 506.

† See Art. '*Vesiculæ Seminales*,' in "Cyclop. of Anat. and Physiol.," vol. iv. p. 1431.

vesicles, but have a sacculated glandular character; and their secretion seems to be of a mucous nature. Into the same part of the urethra is discharged the secretion of the *Prostate Gland*, which is poured forth by a number (15—20) of separate ducts into a depressed fossa on either side; of the nature of this secretion scarcely anything is known, and it can be only surmised that its use, like that of the fluid of the vesiculæ seminales, is to dilute the seminal fluid, and to give it such an increase of bulk that it may be more effectually conveyed within the female passages. It seems probable, indeed, that a certain dilution of the fluid secreted by the testes may be a condition of its power of fecundation; since it has been ascertained by Mr. Newport, that too copious an application of spermatozoa to an ovum is absolutely unfavourable to their action.—That in some way or other both these glandular bodies serve as accessory organs of generation, may be inferred from the fact, that in animals which have only a periodical aptitude for procreation, they undergo an alternate increase and decrease, corresponding with the periodical enlargement and diminution of the testes themselves.

843 The essential peculiarity of the Spermatic fluid, however, consists in the presence of a large number of very minute bodies, the *spermatozoa*, which, from their usually remaining in active motion for some time after they have quitted the living organism, have been erroneously considered as proper Animalcules. The Human Spermatozoon (of which representations are given in Plate I., Fig. 1) consists of a little oval flattened 'body' between the 1-600th and the 1-800th of a line in length, from which proceeds a long filiform 'tail' gradually tapering to the finest point, of 1-50th or at most 1-40th of a line in length. The whole is perfectly transparent; and nothing that can be termed 'structure' can be satisfactorily distinguished within it. Its movements are principally executed by the tail, which has a kind of vibratile undulating motion, they may continue for many hours after the emission of the fluid, and they are not checked by its admixture with other secretions, such as the urine and the prostatic fluid. Thus, in cases of nocturnal emission, the Spermatozoa may not unfrequently be found actively moving through the urine in the morning; and those contained in the seminal fluid collected from females that have just copulated, are frequently found to live many days. Their presence may be readily detected by an observer familiar with their appearance, and furnished with a Microscope of sufficient power, even when they have long ceased to move, and are broken into fragments; and the Physician and the Medical Jurist will frequently derive much assistance from an examination of this kind. Thus, cases are of no uncommon occurrence, especially among those who have been too much addicted to sexual indulgence, in which seminal emissions take place unconsciously and frequently, and produce great general derangement of the health; and the true nature of the complaint is obscure, until the fact has been detected by ocular examination. Again, in charges of rape, in which evidence of actual emission is required, a microscopic examination of the stiffened spots left on the linen will seldom fail in obtaining proof, if the act have been completed: in such cases, however, we must not expect to meet with more than fragments of Spermatozoa; but these are so unlike anything else, that little doubt need be entertained regarding them. It has been proposed to employ the same test, in

juridical inquiries respecting doubtful cases of death by suspension, seminal emissions being not unfrequent results of this kind of violence; but there are many obvious objections which should prevent much confidence being placed in it.*

844. The mode of evolution of the Spermatozoa, first discovered by Wagner, and more perfectly elucidated by Kolliker, is such as to indicate that these bodies are true products of the formative action of the organs in which they are found, and cannot be ranked in the same category with Animalcules. They are developed in the interior of cells, or 'vesicles of evolution,' such as are visible in the seminal fluid in various stages of production (Plate I., Fig. 2, A, B, C), and have been known under the name of 'seminal granules.' These appear to have been themselves formed within parent-cells, which are probably to be regarded as the epithelial cells of the tubuli seminiferi; constituting, like the analogous cells of other glands, the essential elements of the spermatic apparatus. These parent-cells are sometimes observed to contain but a single 'vesicle of evolution,' as shown at D; but more commonly from three to seven are to be seen within them (E). When taken from a body recently dead, and examined without being treated with water or any other agent, they are quite pellucid, and exhibit a delicate contour with perfectly homogeneous contents; very speedily, however, a sort of coagulation takes place within them, by which their contents are rendered granular. Each of these 'vesicles of evolution' gives origin to a spermatozoon, and to one only; the earliest stages of its development have not yet been fully made-out, since it does not at first exhibit those sharp distinct contours, dependent on its great refractive power, which afterwards distinguish it; but it is seen lying in the interior of the cell as a slight linear shadow, at first partly hidden by the surrounding granules (Fig. 3, B), but afterwards without any such obscuration. When the vesicle is completely matured, it bursts, and gives exit to the contained spermatozoon; but it is common for the parent-cells to retain the vesicles of evolution, during the development of the spermatozoa within the latter; so that the spermatozoa set-free by the rupture of these, are still enveloped by the parent-cell. In this condition they have a tendency to aggregation in bundles; and these bundles are finally liberated by the rupture of the parent-cell, after which the individual spermatozoa separate one from another. The spermatozoa are not normally found free in the tubuli seminiferi; although they may be there so far advanced in development, that the addition of water liberates them by occasioning the rupture of their envelopes. In the rete testis and vasa efferentia, the spermatozoa are very commonly found lying in bundles within the parent-cells, the vesicles of evolution having disappeared; and they are usually set-free completely by the time that they reach the epididymis, though still frequently associated in bundles. The earlier phases are occasionally met-with, however, even in the vas deferens.†

845. That the Spermatozoa are the essential elements of the spermatic fluid, may be reasonably inferred from several considerations. There are

* See the Author's Article 'Asphyxia,' in the "Library of Practical Medicine," and the authorities there referred to.

† For the latest researches on the development, &c., of the Spermatozoa, see the elaborate Article 'Semen,' in the "Cyclop. of Anat. and Physiol.," by Drs. Wagner and Leuckardt, and Prof. Kolliker's "Mikroskopische Anatomie," band ii., § 226.

some cases in which the 'liquor seminis' is altogether absent, so that they constitute the sole element of the semen; whilst, on the other hand, they are never wanting in the semen of animals capable of procreation, but are absent, or imperfectly developed, in the semen of hybrids, which are nearly or entirely sterile. Moreover, it may be considered as certain that the absolute contact of the spermatozoa with the ovum (§ 860) is requisite for its fecundation, whilst, on the other hand, if the spermatozoa be carefully removed from the liquor seminis by filtration, the latter is entirely destitute of fertilizing power.* Hence the presence of the Liquor Seminis must be considered as merely incidental; and as answering some secondary purpose, either in the development or in the conveyance of the Spermatozoa.

846. The power of procreation does not usually exist in the Human Male, before the age of from 14 to 16 years; and it may be considered probable that no Spermatozoa are produced until that period, although a fluid is secreted by the testes. At this epoch, which is ordinarily designated as that of *Puberty*, a considerable change takes place in the bodily constitution. the sexual organs undergo a much-increased development, various parts of the surface, especially the chin and the pubes, become covered with hair; the larynx enlarges, and the voice becomes lower in pitch, as well as rougher and more powerful; and new feelings and desires are awakened in the mind. Instances, however, are by no means rare, in which these changes occur at a much earlier period; the full development of the generative organs, with manifestations of the sexual passion, having been observed in children but a few years old. The procreative power may last, if not abused, during a very prolonged period. Undoubted instances of virility at the age of more than 100 years are on record; but in these cases, the general bodily vigour was preserved in a very remarkable degree. The ordinary rule seems to be, that sexual power is not retained by the male to any considerable amount, after the age of 60 or 65 years.

847. To the use of the sexual organs for the continuance of his race, Man is prompted by a powerful instinctive desire (§ 561), which he shares with the lower animals. This Instinct, like the other propensities, is excited by sensations; and these may either originate in the sexual organs themselves, or may be excited through the organs of special sense. Thus in Man it is most powerfully aroused by impressions conveyed through the sight or the touch; but in many other animals, the auditory and olfactory organs communicate impressions which have an equal power, and it is not improbable that, in certain morbidly-excited states of feeling, the same may be the case in ourselves. Localized sensations have also a very powerful effect in exciting sexual desire, as must have been within the experience of almost every one, the fact is most remarkable, however, in cases of Satyriasis, which disease is generally found to be connected with some obvious cause of irritation of the generative system, such as pruritus, active congestion, &c. That some part of the Encephalon is the seat of this as of other instinctive propensities, appears from the considerations formerly adduced; but that the Cerebellum is the part

* This point has been completely established by the researches of Mr. Newport ("Phil. Trans.," 1851), who has repeated and confirmed the experimental results previously obtained by Spallanzani and by Prevost and Dumas.

in which this function is specially located, cannot be regarded as by any means sufficiently proved (§§ 557–561). The instinct, when once aroused (even though very obscurely felt), acts upon the mental faculties and moral feelings; and thus becomes the source, though almost unconsciously so to the individual, of the tendency to form that kind of attachment towards one of the opposite sex, which is known as *love*. This tendency cannot be regarded as a simple passion or emotion, since it is the result of the combined operations of the reason, the imagination, and the moral feelings; and it is in this engraftment (so to speak) of the psychical attachment, upon the mere corporeal instinct, that a difference exists between the sexual relations of Man and those of the lower animals. In proportion as the Human being makes the temporary gratification of the mere sexual appetite his chief object, and overlooks the happiness arising from spiritual communion, which is not only purer but more permanent, and of which a renewal may be anticipated in another world,—does he degrade himself to a level with the brutes that perish. Yet how lamentably frequent is this degradation!

848. When, impelled by sexual excitement, the Male seeks intercourse with the Female, the erectile tissue of the genital organs becomes turgid with blood (§ 282), and the surface acquires a much-increased sensibility; this is especially acute in the Glans penis. By the friction of the Glans against the rugous walls of the Vagina, the excitement is increased; and the impression which is thus produced at last becomes so strong, that it calls-forth, through the medium of the Spinal Cord, a reflex contraction of the muscular fibres of the Vasa Deferentia, and of the muscles which surround the Vesiculæ Seminales and Prostate gland. These receptacles discharge their contents into the Urethra; from which they are expelled with some degree of force, and with a kind of convulsive action, by its own Compressor muscles. Now although the sensations concerned in this act are ordinarily most acutely pleasurable, there appears sufficient evidence that they are by no means essential to its performance; and that the impression which is conveyed to the Spinal Cord *need not* give rise to a sensation, in order to produce the reflex contraction of the Ejaculator muscles (§ 511). The high degree of nervous excitement which the act of coition involves, produces a subsequent depression to a corresponding amount; and the too frequent repetition of it is productive of consequences very injurious to the general health. This is still more the case with the solitary indulgence, which (it is to be feared) is practised by too many youths; for this, substituting an unnatural degree of one kind of excitement, for that which is wanting in another, cannot but be still more trying to the bodily powers. The secretion of seminal fluid being, like other secretions, very much under the control of the nervous system, will be increased by the continual direction of the mind towards objects which awaken the sexual propensity (§ 832); and thus, if a frequent discharge be occasioned, whether by natural or unnatural excitement, a much larger quantity will altogether be produced, although the amount emitted at each period will be less, and its due perfection will not be attained, the fluid under such circumstances being found to contain an unduly-large proportion of immature seminal cells. The formation of the secretion seems of itself to be a much greater tax upon the corporeal powers, than might have been supposed *à priori*; and

it is a well known fact, that the highest degree of bodily vigour is inconsistent with more than a very moderate indulgence in sexual intercourse; whilst nothing is more certain to reduce the powers, both of body and mind, than excess in this respect. —These principles, which are of great importance in the regulation of the health, are but expressions of the general law (which prevails equally in the Vegetable and in the Animal kingdom), that the Development of the Individual, and the Reproduction of the Species, stand in an inverse ratio to each other.

3.—*Action of the Female.*

849. The essential part of the Female Generative system, is that in which the Ova are prepared; the other organs are merely accessory, and are not to be found in a large proportion of the Animal kingdom. In many of the lower animals, the Ovarium consists of a loose tissue containing many areolæ, in which the Ova are formed, and from which they escape by the rupture of the cell-walls; in the higher animals, as in the Human female, the substance of the Ovarium is firm and compact, and consists of a nucleated, tough, fibrous, though not distinctly fibrillar, connective tissue, forming what is known as the *stroma*, and the Ova, except when they are approaching maturity, can only be distinguished in the interstices of this, by the aid of a high magnifying power. The Ovum in all Vertebrated animals is produced within a capsule or bag, the exterior of which is in contact with the stroma of the ovarium; this has been termed, in Mammalia, the *Graafian vesicle*, after the name of its first discoverer; but the more general and appropriate designation of *Ovisac* was given to it by Dr. Barry, who showed that it exists in other classes of Vertebrata.* Between the Ovum and the Ovisac, in Oviparous animals, there is scarcely any interval; but in the Mammalia, a large amount of granular matter (composed of nucleated cells, loosely-aggre-

Fig. 114.

Constituent parts of *Mammalian Ovum*:—A, entire; B, ruptured, with the contents escaping;—*m v*, vitelline membrane; *y*, yolk; *v g*, germinal vesicle; *t g*, germinal spot.

gated together) is present; being especially found adherent to the lining of the ovisac, to which it forms a sort of epithelium, or internal tunic, known as the *membrana granulosa;* whilst it also forms a disk-like in-

* 'Researches in Embryology,' 1st series, in "Philos. Transact.," 1838.

vestment to the ovum, which is termed the *discus proligerus*. The membrane which incloses the yolk in Mammalia, has received, on account of its thickness and peculiar transparency, the distinctive appellation of *zona pellucida* (Fig. 114, *m v*). The yolk or *vitellus* (*j*), which is composed of albumen and oil-particles, with traces of cells, is very small in the Mammalian ovum, its function being limited to the sustenance of the germ during its earliest period of development, and it corresponds rather with that part of the yolk of the egg of the higher Ovipara which has been distinguished as the 'germ-yolk,' in consequence of its direct participation in the formation of the germinal substance (§ 887), than with that which has been termed the 'food yolk,' as not being incorporated with the germ, but being destined for its subsequent nutrition by undergoing conversion into blood.* Occupying the centre of the vitelline mass, in the immature ovum, is a peculiar cell, very different in its aspect from the surrounding substance, which is termed the *germinal vesicle* (Fig. 114, *v g*); and this has a very distinct nucleus (*t g*) known as the *germinal spot*. This cell must be considered as the essential part of the ovum, and as homologous with the 'germ cell' or 'embryonic vesicle' of the Vegetable ovule. The Human Ovum is extremely minute; not measuring above 1-120th of an inch in diameter, and being sometimes no more than half that size. The diameter of the germinal vesicle of the Human ovum has not yet been ascertained, owing to the difficulty of isolating it from the yolk; in the ovum of the Rabbit, it is about 1-720th of an inch; and that of the germinal spot, in the Mammalia generally, is from 1-3600th to 1-2400th of an inch.

850. It appears, from the researches of Valentin and Bischoff, that the Graafian vesicle, or Ovisac, is formed previously to the Ovum, which is subsequently developed in its interior; and it would seem that we may regard it as a *vesicle of evolution* for the ovum, in the same way that the gland-cells of the testis act as vesicles of evolution for the spermatozoa. The development of ovisacs commences at a very early period of life; in the ovaries of some animals, they can be detected almost as soon as these organs are themselves evolved; and in all, they show themselves soon after birth. In Plate I., Fig. 4, is represented the condition of the Graafian vesicles in various stages of development, as they are seen imbedded in the fibrous stroma of the ovarium, in a thin slice from the ovary of a sow three weeks old; by which time the germinal vesicle, which is the first part of the ovum that makes its appearance, has been developed in their interior. The germinal vesicle, which distinctly shows the germinal spot, is surrounded by an assemblage of granules, which gives the first indication of a yolk; and around these, the zona pellucida appears to be subsequently developed. The ovum at first occupies the centre of the Graafian vesicle, but it subsequently removes to its periphery; and, when the contents of the ovisac are undergoing maturation, prior to their escape, the ovum is always found on the side of it nearest to the surface of the ovary. The proper

* It has been recently maintained by Reinhardt, that the Bird's yolk bag is really homologous with the Graafian vesicle of the Mammal and its entire contents, the 'food-yolk' of the former being represented in the latter by the cellular substance surrounding the zona pellucida, which is afterwards developed into the Corpus Luteum. ("Kolliker and Siebold's Zeitschrift," band iii heft 4.)

Ovisac, whose wall is formed of a non-vascular membrane, is surrounded by a vascular layer, which is formed by a condensation of the ordinary stroma of the ovarium; it is this which is usually described as the outer layer of the Graafian vesicle.

851. A continual change seems to be taking-place in the contents of the Ovarium, during the greater part of life; certain of the Ovisacs or Graafian vesicles, and their contents, successively arriving at maturity, whilst others degenerate and die. According to the valuable inquiries of Dr. Ritchie,* it appears that even during the period of childhood, there is a continual rupture of ovisacs and discharge of ova, at the surface of the ovarium. The Ovaria are studded with numerous minute copper-coloured maculæ, and their surface presents delicate vesicular elevations, which are occasioned by the most matured ovisacs; the dehiscence of these takes-place by minute punctiform openings in the peritoneal coat, and no cicatrix is left. At the period of puberty, the stroma of the ovarium is crowded with ovisacs; which are still so minute, that in the Ox (according to Dr. Barry's computation) a cubic inch would contain 200 *millions* of them. The greatest advance is seen in those which are situated nearest the surface of the Ovarium; and in such, the Graafian vesicle, with its two coats, may be distinctly traced. In those animals whose aptitude for conception is periodical, the development of the ova to such a degree that they become prepared for fecundation, is periodical also. This development is made evident, when the parts are examined in an animal which is 'in heat,' by the projection of the Graafian vesicles from the surface (Fig. 115), and it consists not merely in an increase of size, but in certain internal changes presently to be described (§ 856).

Fig. 115.

Ovarium of the Rabbit, at the period of Heat, showing various stages of the extrusion of ova.

852. In the Human female, the period of *Puberty*, or commencing aptitude for procreation, is usually between the 13th and 16th years; it is generally thought to be somewhat earlier in warm climates than in cold,† and in densely-populated manufacturing towns than in thinly-

* "London Medical Gazette," 1844.

† It has been stated, by almost all Physiological writers, that women (like fruits) reach maturity, and that menstruation commences, much earlier in hot climates, particularly between the tropics, than in temperate and very cold countries. From many elaborate and interesting papers which have been published within a few years, however, especially from those of Mr Roberton of Manchester (recently collected in his "Essays on Menstruation, and on Practical Midwifery," 1851), it would seem that the natural period of puberty in temperate climates occurs in a much more extended range of ages and is much more equally distributed through that range, than others have alleged; and that, in other countries, the supposed parallel between plants and fruits does not hold good. The fact seems to be, that this, like other *periodic* phenomena of warm blooded animals, is but little influenced by external temperature, simply because the rate of growth and development, of which these phenomena are the exponents, is determined by the temperature of the body itself, not by that of the surrounding medium. Still it is quite possible that external warmth may have a slight influence in determining early puberty

peopled agricultural districts. The mental and bodily habits of the individual have also considerable influence upon the time of its occurrence, girls brought up in the midst of luxury or sensual indulgence, undergoing this change earlier than those reared in hardihood and self-denial. The changes in which puberty consists, are for the most part connected with the Reproductive system. The external and internal organs of generation undergo a considerable increase of size; the mammary glands enlarge; and a deposition of fat takes-place in the mammæ and on the pubes, as well as over the whole surface of the body, giving to the person that roundness and fulness, which are so attractive to the opposite sex at the period of commencing womanhood. The first appearance of the Catamenia usually occurs whilst these changes are in progress, and is a decided indication of the arrival of the period of puberty, but it is not unfrequently delayed much longer; and its absence is by no means to be regarded as a proof of the want of aptitude for procreation, since many women have borne large families without having ever menstruated. The Catamenial discharge, as it issues from the uterus, appears to be nearly or quite identical with ordinary blood, but in its passage through the vagina, it becomes mixed with the acid mucus exuded from its walls, which usually deprives it of the power of coagulating. If the discharge should be profuse, however, a portion of its fibrin remains unaffected, and clots are formed. In cases in which, by the death of women at this period, an opportunity has been afforded for the examination of the lining membrane of the uterus during menstruation, it is found to be unusually turgid with blood, the veins in particular being much distended, and opening upon the internal surface by capillary orifices, to which valvules are occasionally found attached.* Hence it is scarcely correct to designate the menstrual flux as a 'secretion;' although there is reason to think that it may carry-off, besides blood, certain matters which would be appropriate to the formation of a Decidual membrane (§ 863), but which, if not so employed, become excrementitious.—The interval which usually elapses between the successive appearances of the discharge, is about four weeks; and the duration of the flow is from three to six days. There is great variety in this respect, however, among the inhabitants of different climates, and among individuals; in general, the appearance is more frequent, and the duration of the flow greater, among the residents in warm countries, and among individuals of luxurious habits and relaxed frame, than among the inhabitants of colder climes, or among individuals inured to bodily exertion. The first appearance of the discharge is usually preceded and accompanied by considerable general disturbance of the system, especially pain in the loins and a sense of fatigue in the lower extremities; and its periodical return is usually attended with the like symptoms, which are more or less severe in different individuals.

853. Much discussion has taken-place respecting the causes and purposes of the Menstrual flow, and recent inquiries have thrown great light upon them. The state of the female generative system, during its

ance, as already shown, it tends to maintain a somewhat higher degree of bodily heat (§ 427.)

* See Whitehead "On Abortion and Sterility," pp. 13-37.

continuance, appears to be analogous to the *heat* or periodic sexual excitement, of the lower animals; some of which have a sero-sanguinolent discharge at that period; and among many of which, the ova are entirely extruded by the female before the spermatic fluid of the male reaches them, this occasionally taking-place even in Birds. There is good reason to believe that in the Human female the sexual feeling becomes stronger at the period of menstruation; and it is quite certain that there is a greater aptitude for Conception, immediately before and after that epoch, than there is at any intermediate period. Observations to this effect were made by Hippocrates, and were confirmed by Boerhaave and Haller; indeed coitus immediately after menstruation appears to have been frequently recommended as a cure for sterility, and to have proved successful. This question has been made the subject of special inquiry by M. Raciborski; who affirms that the exceptions to the rule —that conception occurs immediately before or after, or during menstruation—are not more than 6 or 7 per cent. Indeed, in his latest work on this subject,* he gives the details of 15 cases, in which the date of conception could be accurately fixed, and the time of the last appearance of the catamenia was also known; and in all but one of them, the correspondence between the two periods was very close. Even in the exceptional case, the catamenia made their appearance shortly after the coitus; which took place at about the middle of the interval between the two regular periods. When conception occurs immediately before the menstrual period, the catamenia sometimes appear, and sometimes are absent; if they appear, their duration is generally less than usual. The fact that conception often takes-place immediately *before* the last appearance of the catamenia (and not *after* it, as commonly imagined), is one well known to practical men. Numerous cases have been collected by Mr. Girdwood, Dr. Robert Lee, MM Gendrin, Negrier, Raciborski, and others, in which the menstrual period was evidently connected with the maturation and discharge of ova,† but the most complete observations yet made on this subject, are those of Dr Ritchie (loc. cit.). He states that about the period of puberty a marked change usually takes-place in the mode in which the ovisacs discharge their contents; but that this change does not necessarily occur simultaneously with the first appearance of the catamenia; as in some cases, the conditions which obtain in the period before puberty, are extended into that of menstruation. The ovaries now receive a much larger supply of blood; the ovisacs show a great increase in bulk and vascularity, so that, when they appear at the surface of the ovary, they present themselves as pisiform turgid elevations; and the discharge of their contents leaves a much larger cicatrix, and is accompanied by an effusion of blood into their cavity, with other subsequent changes, to be presently described. It would appear, however, that although such a discharge takes place *most frequently* at the menstrual period, yet the two occurrences are not necessarily co-existent, for menstruation

* "Sur la Ponte des Mammifères," Paris, 1844.

† Such, at least, appears to be the legitimate inference from the state of the Ovaries but the cases are very few in which the extruded Ova have been found in the female passages. Two such cases (one of them, however, not altogether satisfactory) were recorded by Dr. Letheby, in "Philos. Transact.," 1852.

may take-place without any such rupture; whilst, on the other hand, the maturation and discharge of mature ova may occur in the intervals of menstruation, and even at periods of life when that function is not taking place. Perhaps the most correct general statement on the subject would be this: that there is a periodic return of Ovarian excitement, which *tends to* the maturation and extrusion of ovules, though it may not always reach that point, whilst there is also a periodic turgescence of the vessels of the lining membrane of the Uterus, which *tends to* the production of a decidual membrane;—but that these two periods, though usually coincident, are not necessarily so; and that either change *may* occur without the concurrence of the other.

854. The duration of the period of aptitude for procreation, as marked by the persistence of the Catamenia, is more limited in Women than in Men, usually terminating at about the 45th year; it is sometimes prolonged, however, for ten or even fifteen years further; but cases are rare in which women above 50 years of age have borne children. There is usually no menstrual flow during pregnancy and lactation; in fact, the cessation of the catamenia is generally one of the first signs, indicating that conception has taken place. But it is by no means uncommon for them to appear once or twice subsequently to conception, and in some women there is a regular monthly discharge, though probably not of the usual character, through the whole period. Some very anomalous cases are on record, in which the catamenia never appeared at any other time than during pregnancy; and were then regular. The absence of the catamenia during lactation is by no means constant, especially if the period be prolonged; when the menstrual discharge recurs, it may be considered as indicating an aptitude for conception; and it is well known that, although pregnancy seldom recurs during the continuance of lactation, the rule is by no means invariable.

855. The function of the Female, during the coitus, is essentially passive. When the sexual feeling is strongly excited, there is a considerable degree of turgescence in the erectile tissue surrounding the vagina, and composing the greater part of the nymphæ and the clitoris; and there is an increased secretion from various glandular follicles.* But these changes are by no means necessary for effectual coition; since it is a fact well established, that fruitful intercourse may take place, when the female is in a state of narcotism, of somnambulism, or even of profound ordinary sleep. It has been supposed by some, that the os uteri dilates,

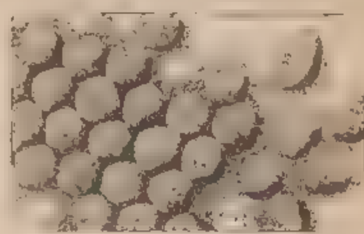
* The glands of Duverney, which have been very accurately described by Professor Tiedemann (1840), and subsequently by M. Huguier in the "Archives d'Anatomie" (1847), seem to be analogous to Cowper's glands, and like them are sometimes wanting, and differ in size. In advanced age they are said to diminish in size, and even to disappear. They are present in the females of all animals, where Cowper's glands exist in the males. They secrete a thick, tenacious, greyish white fluid, which is emitted in large quantity at the termination of the sexual act, most likely from the spasmodic contraction of the constrictor vaginæ muscle, under which they lie. Its admixture with the male semen has been supposed to have some connection with impregnation, but no proof whatever has been given that any such admixture is necessary. It seems not improbable, however, that it may serve, like the prostatic fluid of the male, to give a *dilution* to the seminal fluid that is favourable to its action (§ 842). These glands were probably known to the ancients, and it is doubtless their secretion, which Hippocrates and others describe as the female semen.

by a kind of reflex action, to receive the semen; but of this there is no evidence. The introduction of a small quantity of the fluid just within the vagina, appears to be all that is absolutely necessary for conception; for there are many cases on record, in which pregnancy has occurred, in spite of the closure of the entrance to the vagina by a strong membrane, in which but a very small aperture existed. That the spermatozoa make their way towards the ovarium, and fecundate the ovum either before it entirely quits the ovisac or very shortly afterwards, appears to be the general rule in regard to the Mammalia; and the question naturally arises,—by what means do they arrive there. It has been supposed that the action of the cilia which line the Fallopian tubes, might account for their transit; but the direction of this is *from* the ovaria towards the uterus, and would therefore be opposed to it. A peristaltic action of the Fallopian tubes themselves may generally be noticed in animals killed soon after sexual intercourse; and in those which have a two-horned membranous uterus, such as is evidently but a dilatation of the Fallopian tube, this partakes of the same movement, as may be well seen in the Rabbit; but this peristaltic action, like the ciliary movement, is *from* instead of towards the ovaries. Among the tribes whose ova are fertilized out of the body, the power of movement inherent in the spermatozoa is obviously the means by which they are brought into contact with the ova; and it does not seem unreasonable to suppose, that the same is the case in the higher classes, and that the transit of these curious particles, from the vagina towards the ovaries, is effected by the same kind of action as that which causes them to traverse the field of the microscope. —We shall now consider the changes in the Ovum and its appendages, by which it is prepared for fecundation.

856. Up to the period when the Ovum is nearly brought to maturity, it remains in the centre of the ovisac or inner layer of the Graafian follicle; and it is supported in its place by the 'membrana granulosa,' which is continuous with its proligerous disk. The movement of the ovum towards the surface, which has been already referred-to as a part of the changes by which it is prepared for fecundation, appears from the observations of Valentin to be due to the following cause. In the immature ovisac, the space between its inner layer and the ovum is for the most part filled-up with cells; these, however, gradually dissolve-away, especially on the side nearest the surface of the ovary; whilst an albuminous fluid is effused from the deeper part of the ovisac, which pushes the residual layer (forming the discus proligerus) before it, and thus carries it against the opposite wall. At the same time, there is a gradual thinning away of the various envelopes of the Graafian follicle, as well as of its own walls, in the situation of its most projecting part; and thus it is preparing to give-way at that point, for the discharge of the contained ovum. Before rupture takes place, however, the ovisac itself undergoes a considerable change. Its walls become more vascular externally, and are thickened on their interior by the deposit of a fleshy-looking substance, which, in many of the lower Mammalia, is of a reddish colour, whilst in the Human female it is rather of a yellowish hue. This substance, known as the *Corpus luteum*, is at first entirely composed of an aggregation of cells (Fig. 116), and may, in fact, be considered as an increased development, or hypertrophy, of the 'membranous granulosa' or epithelial

lining of the ovisac, many of its cells, however, especially those in apposition with the enveloping wall of the follicle, undergo a more or less complete transformation into fibres, and thus a gradual transition is established between the cellular substance of the interior of the mass, and the fibrous stroma of the Ovarium itself.* In most domestic quadrupeds, this growth, which sprouts like a mass of granulations from the lining of the ovisac, is often so abundant, if the ovum be impregnated, as not only to fill the cavity of the ruptured vesicle, but even to protrude from the orifice on the surface of the ovary; this orifice subsequently closes, and the contained growth becomes gradually firmer, its colour changing from red to yellow. In the Human female, however, as in the Sow, this new formation is at first less abundant; it does not form mammillary projections from the interior of the ovisac, but lies as a uniform layer upon its lining; and this is thrown into wrinkles or folds, in consequence of the contraction of the ovisac (Fig. 117, *a*—*d*). An irregular cavity is

Fig. 116.



Cells forming the original substance of the *Corpus Luteum*

Fig. 117.

Successive stages of the formation of the *Corpus Luteum*, in the Graafian follicle of the Sow, as seen in vertical section; at *a* is shown the state of the follicle immediately after the expulsion of the ovum, its cavity being filled with blood, and no ostensible increase of its epithelial lining having yet taken place; at *b*, a thickening of this lining has become apparent; at *c*, it begins to present folds which are deepened at *d*, and the clot of blood is absorbed *pari passu*, and at the same time decolorized; a continuance of the same process, as shown at *e*, *f*, *g*, *h*, forms the Corpus Luteum, with its stellate cicatrix.

thus at first left in the interior of the ovisac, after the discharge of the ovum; but this gradually diminishes, partly in consequence of the

* By some observers, as Kölliker, the principal part of the new growth is regarded as the result of a hypertrophy of the internal layer of the fibrous membrane of the original follicle, which, even before the expulsion of the ovum, becomes loosened in texture and augmented in thickness. The fact seems to be, that, as in the case of the Malpighian bodies of the Spleen (§ 142 iii.), there is no distinct line of demarcation between the *fibrous wall* and the *cellular contents* of the follicle.

increased growth of the yellow substance, and partly owing to the general contraction of the ovisac, until it is at last nearly obliterated or reduced to a sort of stellate cicatrix (*e*—*h*). An effusion of blood usually takes place into this cavity, in the Human female, at the time of the rupture of the ovisac; but the coagulum which is left, takes no share in the formation of the yellow body. It generally loses its colouring matter, and acquires the characters of a fibrinous clot; and this may either form a sort of membranous sac, lining the cavity; or it may become a solid mass, occupying the centre of the stellate cicatrix.*

857. The later part of the history of the Corpus Luteum is greatly influenced by the impregnation or non-impregnation of the Ovum whose extrusion it has followed.—If conception do not take-place, the corpus luteum seldom attains a size greater than that of a small pea, and is very commonly less than this; and it begins to diminish about the time of the next menstruation, its shape, which was at first globular, becoming somewhat collapsed and flattened. This diminution is due in the first instance to the absorption of part of its contained coagulum, which usually at the same time loses part of its colouring matter; but contemporaneously with this, there is an increase in the proper yellow substance, which also becomes brighter in colour from the presence of a large quantity of oleaginous matter in its cells. Soon, however, the yellow substance becomes softer and more friable, showing less distinctly the markings of its convolutions, whilst at the same time it becomes more intimately connected with the neighbouring tissues. The central coagulum becomes a faint, whitish, stellate cicatrix, and the yellow substance assumes various irregularities of form, and gradually decreases in size. As a general rule, the corpus luteum of the non-pregnant female, is reduced within six or eight weeks to a very insignificant size, but it may then remain almost unchanged for many months; so that, in the ovaries of females who have menstruated regularly, numerous obsolete corpora lutea may be distinguished.—But if, on the other hand, the discharged ovum should be fertilized, and pregnancy should supervene, the corpus luteum, instead of reaching its maximum of development in three or four weeks and then undergoing atrophy, continues to develope itself for a considerable period, and does not, in fact, become very decidedly retrograde, until after the termination of gestation. This difference relates not only to its size, but also to its aspect and general characters. Its size appears to be usually greatest between the third and the sixth months of pregnancy, it retains its globular or only slightly-flattened form; and it continues to give to the touch a sense of considerable resistance and solidity. The convoluted wall of yellow substance becomes much thicker in proportion to the space in its interior, so that whilst in the non-impregnated female its thickness never exceeds one-eighth of an inch, and is usually much less, that of the pregnant female measures as much as from three-sixteenths to one-fourth of an inch. This substance, moreover, acquires a firmer and more highly organized structure; but instead of presenting an increased brightness of colour, it fades to a dusky and indefinite hue. As, from the time that impregnation takes place, the periodical activity of the ovary is suspended, no new vesicles protrude themselves from its surface until

* This process was first accurately described by M. Pouchet, in his "Théorie Positive de l'Ovulation Spontanée," 1847.

after the completion of gestation; and even those which, at the date of conception, happened to be more or less prominent, appear again to recede. Hence, if the period of pregnancy be at all advanced, the corpus luteum is not found, like that of menstruation, in company with unruptured vesicles in active process of development. After parturition, the corpus luteum rapidly diminishes, though its characteristic structure is still to be distinguished for many months, by close inspection.*

858. The foregoing differences (whose ordinary existence may be considered as well-established, although it may not be affirmed that they present themselves characteristically in each individual case) are probably to be attributed to the increased determination of blood which takes place to the whole Generative apparatus, when it is in a state of exalted functional activity. It is a question, however, of much scientific interest, and one that occasionally becomes of importance in Juridical investigations, what degree of resemblance may exist between the corpus luteum which is formed after the mere extrusion of an ovule, and that which has been modified by the supervention of pregnancy. For it is unquestionable that an unusual development of the fibro-cellular substance may sometimes occur without impregnation, whilst, on the other hand, the changes which usually follow impregnation may take-place so much less characteristically than usual, that the corpus luteum, even at the middle period of pregnancy, may be no larger than that which is often found where pregnancy has not occurred. These variations, which seem mainly to depend upon differences in the degree of vascular excitement of the ovaries, accompanying and succeeding the extrusion of ova, render it impossible to draw any definite line of demarcation, by which we may at once determine what are, and what are not, the results of conception; but the following practical rules, deduced from a consideration of all the circumstances yet known, may be laid down for the guidance of those who find it desirable to have some standard of judgment.—"1. A Corpus Luteum, in its earliest stage (that is, a large vesicle filled with coagulated blood having a ruptured orifice, and a thin layer of yellow matter in its walls), affords no proof of impregnation having taken-place.—2. From the presence of a Corpus Luteum, the opening of which is closed, and the cavity reduced or obliterated, only a stellate cicatrix remaining, also no conclusion as to pregnancy having existed or fecundation having occurred can be drawn, if the corpus luteum be of small size, not containing as much yellow substance as would form a mass the size of a small pea.—3. A similar Corpus Luteum of larger size than a common pea, would be strong presumptive evidence, not only of impregnation having taken place, but of pregnancy having existed during several weeks at least, and the evidence would approximate more and more to complete proof, in proportion as the size of the corpus luteum was greater."†

859. Since the discharge of matured Ova from the ovaries takes-place as independently of sexual intercourse in the Human female (and in the Mammalia generally), as it does in those animals whose ova are fertilized

* See especially the Prize Essay of Dr. J. C. Dalton, "On the Corpus Luteum of Menstruation and Pregnancy," in the "Transact. of the American Medical Association" for 1851, and separately reprinted, Philadelphia, 1851.

† See Dr. Baly's "Supplement to Müller's Physiology," p. 57.

out of the body, it seems unnecessary that the seminal fluid should reach the ovarium in order to effect the fertilization of the ova, since this end may be answered by the contact of the two in the Fallopian tubes, or even in the Uterus itself. From the experiments of Bischoff, however, it appears that in rabbits, bitches, and probably in most other Mammalia, sexual union usually takes-place previously to the escape of the ova from the ovary, and that sufficient time often elapses for the seminal fluid to reach the ovary before their extrusion occurs. In such cases, therefore, it would seem probable that fecundation is effected at the ovary itself. That such occasionally happens in the Human female, seems to be unequivocally proved by the occurrence of tubal or even of ovarian fœtation; the ovum having received the fertilizing influence immediately upon quitting the ovisac, or even before it has entirely extricated itself from the ovary, and having been in some way checked in its transit towards the uterus, so that its development has taken-place in the spot at which it has been arrested. It is affirmed by Bischoff that by the time the ovum reaches the uterus, or even the lower end of the Fallopian tube, its capacity for impregnation is lost; but this assertion chiefly rests on the cessation of sexual desire, observed in those animals in which, after death, the ova were found in these situations. There is every reason to believe that this is not the case in the Human female; for although the sexual desire may be the strongest about the period of the maturation and escape of the ova, yet it is by no means wanting at other times, and the occasional occurrence of cases in which impregnation has taken-place from a single coitus in the middle of the interval between the menstrual periods, shows either that the ovum may retain its capacity for impregnation for some time after its escape from the ovary, or that its maturation and extrusion are not by any means invariably coincident with the menstrual period.*—The ova, when set-free from the ovaries by the rupture of the ovisacs and the giving-way of their several envelopes, are received by the fimbriated extremities of the Fallopian tubes, which, during the period of sexual excitement, appear to be closely applied to the surface of the ovaries. Their conveyance along the Fallopian tubes is probably due in part to the peristaltic movement of their walls, and in part to the action of the cilia which clothe their internal surface.

860. The object of the changes which have been already described, is to bring the Ovum within the reach of the fecundating influence, and to convey it into the uterus after it has been fertilized: we have now to consider the changes of the Ovum itself, which take-place during the same epoch.—At about the same period that the ovum moves towards the periphery of the Graafian follicle, the germinal vesicle moves towards the periphery of the yolk; and it always takes-up its position at the

* See a case of this kind recorded by Dr. Oldham in the "Medical Gazette," July 13, 1849. Instances are certainly not unfrequent, in which conception has taken place five or six days after the conclusion of the menstrual period; the Author has himself known one in which this occurred, after the menstrual flow itself had persisted for a week. It has been urged that the known fertility of the Jewish females, who abstain from sexual intercourse for eight days, or even thirteen days, after the termination of the catamenia, is opposed to the idea that the menstrual period is that of 'heat;' but there is reason to believe that this is to be accounted for in another way,—namely, by the usual occurrence of conception from intercourse immediately *before* the access of the catamenia. (See Mr. Girdwood, in the "Lancet," Dec. 14, 1844.)

precise point of the zona pellucida which is nearest the ovisac, and which is closest, therefore, to the surface of the ovary. Moreover, the germinal spot is always on that part of the germinal vesicle, which is in closest contact with the zona pellucida. Thus, the germinal spot is very near the exterior of the ovary; but it is separated from the peritoneal coat of the latter, by a thin layer of its stroma forming the external wall of the Graafian follicle, by the ovisac forming its internal membrane, and by the zona pellucida. As soon as these give way, there is nothing to prevent the spermatozoa from coming into direct contact with the ovum, even before it quits the ovisac. That such contact is an essential condition of fecundation, there is every reason to believe; although, as to the precise manner in which it operates, we are at present in the dark. There can be no doubt that it is in the contact of the spermatozoa with the ovum (§ 845), and in the changes which occur as the immediate consequence of that contact, that the act of Fecundation essentially consists. The most recent observations of the late Mr. Newport upon the process of impregnation of the Frog (some of which the Author, through the kindness of Mr. N., had the opportunity of verifying), show that the spermatozoa become imbedded in the gelatinous envelope of the ovum, within a few seconds after they come into contact with it; and that they then absolutely pass through the vitelline membrane, into the interior of the Ovum,* where they probably undergo a gradual diffluence; and thus the product of the 'sperm-cell' may be absorbed into the 'germ-cell,' and may intermingle with its contents, the Spermatozoon being nothing else than an embodiment of the fertilizing material developed within the sperm-cell, which is endowed with a temporary power of movement in order that it may find its way to the Ovum. It has been remarked by Mr. Newport, that Spermatozoa whose spontaneous *motility* has ceased, no longer possess the fecundating power; and this fact concurs with other phenomena to indicate, that it is not only a certain *material*, but a *vital force* of which that material is (so to speak) the vehicle, which is required to effect this most important operation.

861. The precise share which the Germinal Vesicle performs, in the changes which take-place in the ovum about the period of fecundation, has not yet been satisfactorily determined. According to Dr. Barry (loc. cit.), the germinal vesicle becomes filled with a new development of cells, which sprout, as it were, from its nucleus (the germinal spot); and after fecundation, a pair of cells is seen in the space previously occupied by the pellucid centre of the nucleus, which is developed at the expense of the rest, and is the true foundation of the embryonic structure. This view is to a certain extent confirmed by the observations of Wagner on the ova both of Frogs and Mammalia, and by those of Vogt on those of the *Rana obstetricans*; both of which lead to the belief that such a process of cell formation does take-place within the germinal vesicle, but that, instead of the further development being carried-on within the

* "Philos. Transact.," 1853, pp. 266-281. Prof. Bischoff, the highest authority on this subject, who had disputed the validity of all previous observations on the penetration of the Spermatozoa into the interior of the Ovum, has fully confirmed those of Mr. Newport, whose lamented death prevented him from enjoying the satisfaction which this testimony to his accuracy would have afforded him. See also Dr. Barry in "Philos. Transact.," 1840, p. 533; and Dr. Ransome, in "Proceed. of Roy. Soc.," Nov. 23, 1854.

germinal vesicle, as maintained by Dr. Barry, this ruptures and sets-free the cells that had been developed in its interior, which are now dispersed through the yolk, whose ulterior changes take-place under their influence Mr. Newport's view is nearly the same as this; and he states that, in the Frog, this dissolution of the germinal vesicle and diffusion of its contents take-place as a preparation for fecundation, and not in consequence of it.* That the germinal vesicle is no longer to be seen when the metamorphoses of the yolk have commenced, is now universally admitted; but with regard to the antecedent process just described, there is still a want of accordance amongst Embryologists, its existence being altogether denied by Bischoff, who maintains that the germinal vesicle simply dissolves away shortly after coition. The Author is strongly inclined to believe, however, from his own observations, as well as from *à priori* considerations based on the history of Vegetable fertilization, that there *is* a development of cells within the germinal vesicle, at the time of its maturation; and that it is by the influence of the spermatic fluid upon one of these cells, after it has been set-free in the midst of the yolk by the rupture or diffluence of the germinal vesicle, that the first cell of the embryonic fabric is generated.

862. Having thus noticed the principal points of the history of the development and impregnation of the Ovum, we shall proceed to consider the provisions made for the Nutrition of the Embryo, through the Generative apparatus of its female Parent, up to the time of parturition; deferring the history of its own Development for that separate consideration which the importance of this subject demands (Sect 4).—About the time that the ovum is leaving the ovary, the cells of the proligerous disk which immediately surrounds the zona pellucida become club-shaped, their small ends being applied to the surface of the ovum, so as to give it somewhat of a stellate appearance. According to Bischoff, these cells entirely disappear from the ovum of the Rabbit, as soon as it has entered the Fallopian tube; whilst in the Bitch they become round, and continue to invest the ovum in this form throughout its whole transit to the uterus. During its passage, the ovum acquires a sort of gelatinous envelope, which is enclosed in a membrane of fibrous texture, termed the *Chorion*. This envelope is probably of an *albuminous* nature in reality, corresponding with the 'white' of the Bird's egg, whilst the fibrous texture of the chorion seems to be produced, like the membranous basis of the egg-shell of the bird (PRINC. OF GEN. PHYS.), by the exudation of fibrin from the lining membrane of the Fallopian tube or oviduct. The outer layer of this envelope, in the egg of the Bird, is consolidated by the deposition of particles of carbonate of lime in its areolæ, and none of it undergoes any further organization. The Chorion of the Mammal, on the other hand, is destined to undergo changes of a much higher order; which adapt it for participating, to a most important degree, in the nutrition of the included embryo. The first of these changes consists in the extension of the cellular surface of the membrane into a number of villous prolongations, which give it a spongy or shaggy appearance (Fig. 122); these serve as absorbing radicles, and form the channel through which the embryo is nourished by the fluids of the parent, until a more perfect communication is formed by the subsequent extension of vessels into them (§ 865).

* "Philos. Transact.," 1851, p 178.

863. We have now to speak of the changes in the Uterus, which take place in consequence of Conception, and which prepare it to receive the ovum. Of these the most important is the formation of the Membrana *Decidua*, so called from its being cast-off at each parturition. This membrane has been usually supposed to be a new formation; and has been described as originating in coaguable lymph thrown out on the inner surface of the uterus, into which vessels are prolonged from the subjacent substance. It appears, however, from the researches of Profrs. Sharpey and Weber,* that this is not the true account of it, and that the Decidua vera is really composed of the inner portion of the Mucous membrane itself, which undergoes a considerable change in its character. The Mucous membrane of the uterus possesses on its free surface, a tubular structure (Figs. 118, 119), not very unlike that which has been described

Fig. 118

Fig. 119

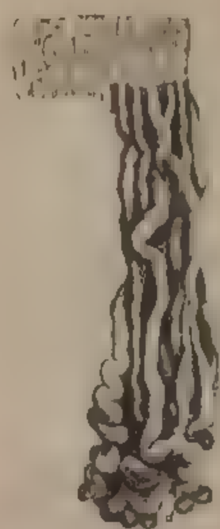


Fig. 118. Section of the *Lining Membrane of a Human Uterus* at the period of commencing pregnancy, twice the natural size, showing the arrangement and other peculiarities of the glands *d*, *d*, *d*, with their orifices, *a*, *a*, *a*, on the internal surface of the organ.

Fig. 119. A portion of Fig. 118 more enlarged, showing the convoluted extremities of the tubular glandulæ.

as existing in the lining membrane of the stomach (§ 94). This tubular portion becomes thickened and increased in vascularity, within a short time after conception; and when the inner surface of a newly impregnated Uterus is examined with a low magnifying power, the orifices of its tubes are very distinctly seen, being lined with a white epithelium. The blood-vessels form a very minute network, which extends in loops

* Müller's "Elements of Physiology," pp. 1574-1580.

from the subjacent portion of the membrane. According to the observations of Prof. Goodsir,* the interfollicular spaces also are crowded with nucleated particles; and it is to the development of this interfollicular substance, as well as to the enlargement of the follicles themselves, and the copious development of epithelial cells in their interior, that the mucous membrane in this condition owes its increased thickness. This increased development appears to have reference in part to the temporary nutrition of the Ovum, and in part to the further evolution of the decidual substance itself in the formation of the Placenta. The cavity of the Uterus shortly becomes filled with a fluid, evidently poured-out from the follicles in its walls, and containing a large number of nucleated cells; and in this the villi of the chorion imbed themselves, obviously for the purpose of deriving from it the materials required for the development of the embryonic structures. These villi are easily traced in the Bitch (as Dr. Sharpey first pointed-out) into the mouths of the uterine glandulæ, some of which are composite in their structure, a single outlet being common to a number of follicles; but they have not yet been so traced in the Human subject.

864. The Deciduous membrane is found at a later period to consist of two layers; the *Decidua vera* lining the uterus, and the *Decidua reflexa* covering the exterior of the ovum. Regarding the origin of this second layer, there has been a good deal of difference of opinion. The doctrine first propounded by Dr. W. Hunter, which is indicated by the name he bestowed upon the membrane, was that the 'decidua reflexa' is a portion of the true decidua, which has been pushed before the ovum at its entrance into the uterus; it being supposed that the true decidua forms a completely closed sac (like that of a serous membrane), against the *outside* of which the ovum is applied, so that it comes to be invested by a double layer of it, as the heart is by the pericardium, or the lungs by the pleura. But this view is negatived by a number of considerations. For, in the first place, the original decidua does not form the closed sac which this supposition involves, but extends (like the mucous membrane of which it is a metamorphosed form) into the Fallopian tubes; and the ovum, at its entrance into the uterus, really lies upon its internal surface. But again, the texture of the two layers is very different; for, as was first pointed out by Prof. Goodsir (loc. cit.), the decidua reflexa is almost entirely composed of cells, exhibiting few or none of the orifices of the glandular follicles which are characteristic of the decidua vera, except near the part where the two layers are continuous. According to the observations of M. Coste, however, there is a considerable resemblance between the two layers at an early period; and he considers the following to be the mode in which the second investment is formed. When the ovum

FIG. 120.

First stage of the formation of the *Decidua reflexa* around the Ovum.

* "Anatomical and Physiological Observations," chap. ix.

enters the uterus, it becomes partially imbedded in the substance of the decidua, which is as yet quite soft (Fig. 120), and thus, receiving an increased nutrition at the part with which the ovum comes into contact, grows-up around it, very much after the manner in which the fleshy granulations grow up around the pea imbedded in a caustic issue. This extension of the decidual substance continues (Fig 121), until it has completely enveloped the ovum, and it is thus, according to him, that the decidua reflexa is formed, in continuity with the decidua vera.* As the ovum increases in size, the cavity between the decidua vera and the decidua reflexa gradually diminishes, and by the end of the 3rd month the two layers come into contact, and are henceforth scarcely or not at all distinguishable.

FIG. 121

More advanced stage of *Decidua reflexa*

865. The surface of the Ovum, thus surrounded by the double layer of the deciduous membrane, is rendered shaggy by the growth of villous tufts from the surface of its investing Chorion (Fig. 122). Each of these tufts, as was first pointed-out by Prof. Goodsir (loc. cit.), is composed of an assemblage of nucleated cells, which are found in various stages of development, and these are always enclosed within a layer of basement-membrane, which seems to be itself composed of flattened cells united by their edges. At the free extremity of each villus is a bulbous expansion, the cells composing which are arranged round a central spot; and it is at this point that the most active processes of growth take-place, the villus elongating by the development of new cells from its germinal spot, and (like the spongiole of the plant) drawing-in nutriment from the soil in which it is imbedded.—In its earliest grade of development, the chorion and its villi contain no

FIG. 122.

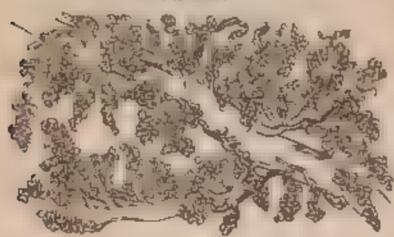
Entire *Human Ovum* of 8th week, sixteen lines in length [illegible] reckoning the tufts; the surface of the Chorion partly smooth and partly rendered shaggy by the growth of tufts.

* This doctrine was first announced by M. Coste, in a communication to the Parisian Academy of Sciences, on the basis of observations on two Uteri at the 20th and 25th days of gestation. (See "Comptes Rendus," Mai 24, 1847.) It seems to be that which is altogether most in harmony with observed facts, and especially with those noticed by Professors Sharpey and Weber. See, also, the Memoir of M. Robin, on the Mucous Membrane of the Uterus, in the "Archiv. Gen. de Méd.," 4e Ser., tom. xvii. xviii.

vessels; and the fluid drawn-in by the tufts is communicated to the embryo, by the absorbing powers of the germinal membrane of the latter. But when the tufts are penetrated by blood vessels, and their communication with the embryo becomes more direct, the means by which they communicate with the parent are found to be still essentially the same, namely, a double layer of nucleated cells, one layer belonging to the fœtal tuft, and the other to the vascular maternal surface. It is from these elements that the *Placenta* is formed.

866. The first stage in this process consists in the extension of the Fœtal vessels into the villi of the Chorion over its entire surface, in the manner hereafter to be detailed (§ 893), so that the nutriment which these villi imbibe, instead of being merely added to the albuminous fluid surrounding the yolk bag, is now conveyed directly to the embryo. This—the earliest and simplest mode by which the Fœtus effects a new connection with the parent—is the only one in which it ever takes-place in the lower Mammalia, which are hence properly designated as 'non-placental,' rather than as ovo-viviparous. In the higher Mammalia, however, there soon occurs a great extension of the vascular tufts of the fœtal chorion, at certain points, and a corresponding adaptation, on the part of the uterine structure, to afford them an increased supply of nutritious fluid. These specially-prolonged portions are scattered, in the Ruminantia and some other Mammalia, over the whole surface of the chorion, forming what are termed the 'cotyledons;' but in the higher orders, and in Man, they are concentrated in one spot, forming the Placenta. In some of the lower tribes, the maternal and the fœtal portions of the placenta may be very easily separated; the former consisting of the thickened Decidua, and the latter being composed of the prolonged and ramifying muscular tufts of the Chorion, dipping-down

FIG. 123.



Portion of the ultimate ramifications of the Umbilical vessels, forming the *Fœtal Villi of the Placenta*.

FIG. 124.

Portion of one of the *Fœtal Villi*, about to form part of the Placenta, highly magnified:—*a, a*, its cellular covering; *b, b, b*, its looped vessels; *c, c*, its basis of connective tissue.

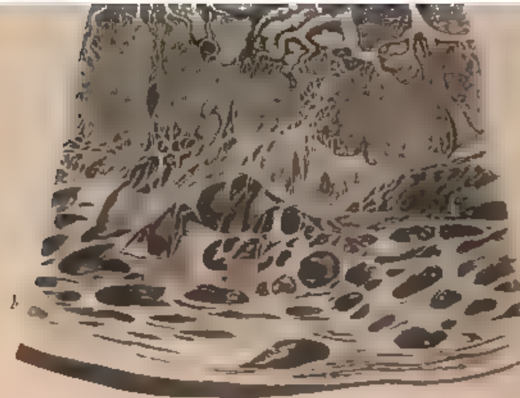
into it. But in the Human placenta, the two elements are mingled together through its whole substance. On looking at the fœtal surface of the Human placenta, we perceive that the umbilical vessels diverge in every direction from the point at which they enter it; and their subdivisions form a large mass of capillaries, arranged in a peculiar manner (Figs. 123, 124), and constituting what are known as the *fœtal villi*. Each villus contains one or more capillary loops, communicating with an artery on one side, and with a vein on the other; but the same capillary may pass into several villi, before re-entering a larger vessel. The capillaries of the villi are covered, as in the chorion, by a layer of cells (Fig. 124, *a*, *a*, Fig. 125, *f*), inclosed in basement-membrane (*e*); but the fœtal tuft thus formed is inclosed in a second series of envelopes (Fig. 125, *a*, *b*, *c*), derived from the maternal portion of the placenta,—a space (*d*) being left, however, between the two, at the extremity of the tuft.

867. Whilst the *fœtal* portion of the Placenta is thus being generated by the extension of the vascular tufts of the Chorion, the maternal portion is formed by the enlargement of the vessels of the Decidua, between which they dip-down. "These vessels assume the character of sinuses, and at last swell-out (so to speak) around and between the villi, so that finally the villi are completely bound-up or covered by the membrane which constitutes the walls of the vessels, this membrane following the contour of all the villi, and even passing to a certain extent over the branches and stems of the tufts. Between this membrane, or wall of the enlarged decidual vessels, and the internal membrane of the villi, there still remains a layer of the cells of the decidua."* In this manner is formed the *maternal* portion of the placenta, which may be regarded in its adult state (as was well pointed-out by Dr. J. Reid†) in the light of a large sac formed by a prolongation of the inner coat of the uterine vessels; against the fœtal surface of which sac, the tufts just described may be said to push themselves, so as to dip-down into it, carrying before them a portion of its thin wall, which constitutes a sheath to each tuft. Now as every extension of the uterine vessels carries the decidua before it, every one of the vascular tufts that dips-down into it, will be covered with a layer of the cellular structure of the latter; and the fœtal portion of each tuft will thus be inclosed in a layer of *maternal* cells and basement-membrane (Fig. 125, *a*, *b*, *c*). In this manner, the whole interior of the Placental cavity (Fig. 126) is intersected by numerous tufts of fœtal vessels disposed in fringes, and bound-down by reflexions of the delicate

FIG. 125.

Extremity of a *Placental Villus*. *a*, external membrane of the villus, continuous with the lining membrane of the vascular system of the mother; *b*, external cells of the villus, belonging to the placental decidua; *c*, *c*, germinal centres of the external cells; *d*, the space between the maternal and fœtal portions of the villus; *e*, the internal membrane of the villus, continuous with the external membrane of the chorion; *f*, the internal cells of the villus, belonging to the chorion; *g*, the loop of umbilical vessels.

* Prof. Goodsir's "Anatomical and Pathological Observations," p. 60.
† "Edinb. Med. and Surg. Journ.," Jan. 1841; and "Anat., Phys., and Pathol. Researches," Chap. VIII.



Section of a portion of a fully formed *Placenta*, with the part of the Uterus to which it is attached: *a*, umbilical cord; *b*, *b*, section of uterus showing the venous sinuses; *c*, *c*, branches of the umbilical vessels; *d*, *d*, curling arteries of the uterus.

view was suggested to Dr. Reid by the very interesting fact, that tufts of fœtal vessels not unfrequently extend beyond the uterine sur of the placenta, and dip-down into the uterine sinuses (Fig. 127), wh

Fig. 127.

selves, namely, a fold of the lining membrane of the decidual sinuses, and a layer of the cellular decidua.

868. The Maternal blood is conveyed into the Placental cavity by the 'curling arteries' of the uterus (Fig. 126, *d*, Fig. 127, *c*), and is received back from it into the large veins that are commonly designated as sinuses (Figs. 126, 127, *b b*). The fœtal vessels (Fig. 126, *e, e*, Fig. 127, *e, e*) being bathed in this blood, as the branchiæ of aquatic animals are in the water that surrounds them, not only enable the fœtal blood to exchange its venous character for the arterial, by parting with its carbonic acid to the maternal blood, and receiving oxygen from it; but they also serve as rootlets, by which certain nutritious elements of the maternal blood (probably those composing the liquor sanguinis) are taken into the system of the fœtus. In this, they closely correspond with the villi of the intestinal canal, and there is this further very striking analogy,—that the nutrient material is selected and prepared by two sets of cells, one of which (the maternal) transmits it to the other (the fœtal), in the same manner as the epithelial cells of the intestinal villi seem to take-up and prepare the nutrient matter, which is destined to be still further assimilated by the cells that float in the circulating current (§ 121). It is probable, too, that the Placenta is to be regarded as an excreting organ: serving for the removal, through the maternal blood, of excrementitious matter whose continued circulation through the blood of the fœtus would be prejudicial to the latter. And it will be in this mode, that the blood of the mother may become impregnated with substances, or impressed with attributes, originally belonging to the male parent; so as to impart these to the products of subsequent conceptions by a different father (§ 881). There is no more direct communication between the mother and fœtus, than that which is afforded by this immersion of the fœtal tufts in the maternal blood; all the observations which have been supposed to prove the existence of real vascular continuity, having been falsified by the extravasation of fluid, probably consequent upon the force used in injecting the vessels. Moreover, the different size of the blood-corpuscles in the fœtus and in the parent (§ 167) shows the non-existence of any such communication.

869. The formation of the Placenta, in the manner just described, commences in the latter part of the second month; during the third, the organ acquires its proper character; and it subsequently goes-on increasing, in accordance with the growth of the Ovum. Towards the end of the term of gestation, however, it becomes more dense and less vascular; owing, it would seem, to the obliteration of several of the minuter vessels, which are converted into hard fibrous filaments. The vessels of the Uterus undergo great enlargement throughout, but especially at the part to which the placenta is attached; and the blood in moving through them produces a peculiar murmur, which is usually distinctly audible at an early period of pregnancy, and may be regarded (when due care is taken to avoid sources of fallacy), as one of its most unequivocal positive signs. The 'placental bruit' is thus described by Dr. Montgomery.* "The characters of this phenomenon are, a low murmuring or somewhat cooing sound, resembling that made by blowing

* "Signs of Pregnancy," p. 121

gently over the lip of a wide-mouthed phial, and accompanied by a slight rushing noise, but without any sensation of impulse. The sound is, in its return, exactly synchronous with the pulse of the mother at the time of examination, and varies in the frequency of its repetitions, with any accidental variation which may occur in the maternal circulation. Its situation does not vary during the course of the same pregnancy; but in whatever region of the uterus it is first heard, it will in future be found, if recognized at all,—for it is liable to intermissions, at least, we shall occasionally be unable to hear it where we have already heard it a short time before, and where we shall shortly again recognize it. According to my experience, it will be most frequently heard about the situation of the Fallopian tube of the right side; but it may be detected in any of the lateral or anterior parts of the uterus." That the cause of this sound exists in the Uterus itself, is distinctly proved by the fact, that it has been heard when that organ was so completely *anteverted*, that the fundus hung-down between the patient's thighs. A sound so much resembling this as to be scarcely distinguishable from it, may be occasioned, however, by a cause of a very different nature,—namely, an abdominal tumour, pressing upon the aorta, iliac arteries, or enlarged vessels of its own; and, in doubtful cases, it is necessary to give full weight to the possibility of such an explanation. The sound may be imitated at any time, by pressing the stethoscope on the iliac arteries. The placental bruit has been not unfrequently heard in the 11th week, but it cannot generally be detected before the fourth month, when the fundus uteri rises above the anterior wall of the pelvis.

870. The increase in the size of the Uterus, which takes-place *pari passu* with the enlargement of the ovum, is accompanied with a remarkable augmentation in the amount of its substance. Up to about the fifth or sixth month, not only its cavity, but the thickness of its walls, is progressively added to; from that time to the end of gestation, the thickness of the walls diminishes whilst the cavity increases, but not in an equal proportion; and at the conclusion of parturition, its solid bulk is estimated at about twenty-four times that of the unimpregnated Uterus. The augmented volume of the organ is chiefly due to the increased development of its Muscular coat, which is composed of the fusiform cells with staff-shaped nuclei, that make-up the 'non-striated' muscular fibre elsewhere. According to Prof. Kolliker, a vast amount of new fibres are generated during the early months of pregnancy; but there is at the same time an extraordinary increase in the size of those previously formed, their length being multiplied from seven to eleven times, and their width from twice to five times. After the sixth month, the origination of new muscular fibres seems to cease, but the augmentation in the size of those already generated seems to continue. The connective tissue which unites the muscular fibres, also increases during pregnancy, and becomes more distinctly fibrous.* It has been affirmed that the Nervous substance of the Uterus also undergoes a great augmentation during pregnancy, but of this no sufficient evidence has yet been adduced.—Simultaneously with the enlargement of the uterus, the Mammary Gland and its appen-

* See Kölliker's "Manual of Human Histology" (Syd. Soc.'s Ed.), vol. ii., p. 258, 257.

dages undergo a fuller development; and from this a valuable, but not unequivocal, indication of pregnancy may be drawn. Occasional shooting pains in the Mammæ are not unfrequently experienced within a short period after conception; and more continued tenderness is also not unusual. A sense of distension is very commonly experienced at about the end of the second month, and from that time a distinct 'knottiness' usually begins to present itself, increasing with the advance of pregnancy. In many instances, however, these mammary sympathies are entirely absent, and they may be simulated by changes that take place in consequence of various affections of the uterus. A change of colour in the areola is a very common, but not an invariable, occurrence in the early months of pregnancy; but another sign is afforded by the areola and nipple, which is of more value because more constant,—namely, a puffy turgescence, and an increased development of the little glandular follicles, or tubercles, which commonly secrete a dewy moisture.—Many other changes in the constitution occur during pregnancy; indicated by the buffiness of the blood, the irritability of the stomach, and the increased excitability of the mind. All these, however, are discussed with sufficient amplification, in works on Obstetric Medicine.

871. The act of Conception, being one of a purely organic nature, is not itself productive of any sensation on the part of the mother; but there are some women in whom it is attended with certain sympathetic affections, such as faintness, vertigo, &c., that enable them to fix upon the particular time at which it has taken place. From that period, however, the mother has no direct consciousness of the change going-on in the uterus (save by the effects of its increasing pressure on other parts), until the occurrence of what is termed 'quickening.' This is generally described as a kind of fluttering movement, attended with some degree of syncope or vertigo. After it has once occurred, and has strongly excited attention, it is occasionally renewed once or twice, and then gives-place to the ordinary movements of the fœtus. Not unfrequently, however, no movement whatever is felt, until near the end of the term of gestation, or even through the whole of it. As to the cause of the sensation, Obstetricians are much divided; and no satisfactory account has been given of it. It has been vulgarly supposed to be due to the first movement of the fœtus, which was imagined then to become possessed of an independent life; and the English law recognizes the truth of this doctrine, in varying the punishment of an attempt to procure Abortion, according to whether the woman be 'quick with child' or not; and in delaying execution when a woman can be proved to be so, though it is made to proceed if she is not, even if she be unquestionably pregnant. Whether or not the first *sensible* motions of the fœtus are the cause of the peculiar feeling in question, there can be no doubt that the embryo has as much independent vitality before, as after, the quickening. From the time that the ovum quits the ovary, it ceases to be a part of the parent, and is dependent on it only for a due supply of nourishment, which it converts, by its own inherent powers, into its proper fabric. But this dependence cannot be said to cease at the moment of quickening; for the connection must be prolonged during several weeks, before the fœtus becomes capable of sustaining life without such assistance. The earliest period at which this may occur, will be presently considered (§ 876).

872. At the conclusion of about forty weeks, or (less correctly) nine solar months,* from the period of conception, the time of Parturition arrives. In this act, the muscular walls of the Uterus are primarily concerned; for a kind of peristaltic contraction takes-place in them, the tendency of which is to press the contents of the cavity from the fundus towards the os uteri, and finally to expel them; and this contraction is alone sufficient to empty the uterus, when no impediment is presented to the exit of the fœtus, as we see in the occasional occurrence of *post-mortem* parturition. It is, in fact, in the contraction of the fibres of the fundus and body of the uterus, and in a relaxation of those about the cervix (which relaxation is something quite different from a mere yielding to pressure, and is obviously a vital phenomenon that marks a peculiarity in the actions of this part), that the first stage of an ordinary labour essentially consists. There is no proof whatever, that these changes are dependent upon nervous influence; in fact, there is much evidence that the parturient action of the uterus is *not* the result (as some have maintained it to be) of a 'reflex' action of the Spinal Cord, but is due to its inherent contractility, for numerous instances have occurred, in which normal parturition has taken-place, notwithstanding the destruction of the lower part of the Cord, or the existence of a state of complete paraplegia which marked its functional inactivity; and the continuance of the peristaltic action for some time after somatic death, when neither the Cerebro-spinal nor the Sympathetic system can afford any supply of nervous power, is a yet more satisfactory proof of the same position.—Nevertheless, it seems quite certain that muscular contractions of the Uterus *may be* induced by reflex action; for in no other way can we account for numerous phenomena, which distinctly mark the operation of remote causes acting through the nervous system, such as the induction of uterine contractions by the dash of cold water on the abdominal surface, by the injection of cold water into the vagina, by the ingestion of cold water into the stomach, or even by dipping the hands into cold water, or again by the suctorial application of the infant's lips to the nipple, by the introduction of the hand into the vagina, by violent movements of other parts of the body, and by various other means. This general fact has an important practical bearing; since there are various occasions on which it is most important to life, that the previously-flaccid uterus should be excited to vigorous contraction, for the sake of accelerating parturition or of suppressing hæmorrhage, whilst, on the other hand, it is often no less important to be able to prevent or to antagonize the operation of causes which would prematurely induce uterine contractions, to the destruction of the offspring and the danger of the mother.

* Although 'nine months' is usually spoken-of as the term of Gestation, yet the real term of forty weeks exceeds this by from five to seven days, according to the months included. The mode of reckoning customary among women, is to date from the middle of the month after the last appearance of the Catamenia; but it is certain that Conception is much more likely to take place *soon* after they have ceased to flow, or even just before their access, than in the intervening period (§ 853); so that, in most instances, it would be most correct to expect labour at forty weeks and a few days after the last recurrence of the Menses.—The period of Quickening may be relied-on in some women, in whom it occurs with great regularity in a certain week of pregnancy; but in general there is great latitude as to the time of its occurrence. The usual or average time seems to be about the 18th week of gestation.

873. When, in the normal act of Parturition, the head has so far made its way through the os uteri as to begin to distend the lower part of the genital canal, a new kind of expulsive effort is superadded to that of the Uterus itself; the assistance of the Expiratory muscles being then called in (§ 511), through the intermediation of the Spinal Cord, which is probably excited to this action by the stimulus thus applied to the afferent nerves of the compressed parts; and it is chiefly by the instrumentality of these muscles, that the normal act of parturition is usually completed. The same action which expels the fœtus, generally also detaches the placenta; and if the uterus contract with sufficient force after this has been thrown-off, the orifices of the vessels which communicate with it are so effectually closed, that little or no hæmorrhage takes place. If, however, the uterus does not contract, or relaxes after having contracted, a large amount of blood may be lost in a short time from the open orifices. For some little time after parturition, a sero-sanguineous discharge, termed the *lochia*, is poured-out from the uterus, and this commonly contains shreds of the deciduous membrane, which had not been previously detached, together with a quantity of fat-globules, and other products of disintegration of the uterine tissue (§ 349).* Within a few weeks after delivery, the uterus regains (at least in a healthy subject) its previous condition; part of its newly-generated muscular fibres seem to disappear altogether, whilst the others shrink to their ordinary dimensions; and the portion of its mucous membrane which had been thrown off as Decidua, seems to be reproduced in the course of the second or third month.

874. As to the reason why the period of Parturition should be just forty weeks after the occurrence of Conception, we know nothing more than we do of that of similar *periodical* phenomena in the history of the life of Man and of other living beings; all of which must be considered as *occasional* manifestations of changes that are *constantly* in progress, whose rate, being dependent upon the degree of Heat supplied, is so uniform in warm blooded animals, as to secure a very close conformity to a common standard.† There is evidence that the occurrence of the uterine *nisus* may be induced by a variety of causes, several of which probably concur in the normal act of Parturition. For, in the first place, the state of development of the muscular substance of the Uterus can scarcely be without a considerable influence on this operation. We see it undergoing a gradual augmentation during the period of pregnancy, without any demand being made upon its functional activity; it gradually becomes

* In addition to the evidence above referred to, of the rapid occurrence of fatty degeneration of the uterine structure after parturition, the Author may mention that he has been informed by Dr. Retzius (Professor of Midwifery at Stockholm) that he has detected a large number of fat-globules in the urine of puerperal women. Is it not possible (it may be further asked) that some of the oleaginous matter so copiously poured forth by the Mammary glands, may be derived from this source? Such an economy of nutrient material would be consistent with what we elsewhere meet with; and the idea is conformable to the fact, that the proportion of butyrine in the milk is much greater in the earlier, than in the later months of lactation (§ 923).

† This may be best illustrated by the analogy of a Leyden jar which is being charged by the *continuous* action of an Electrical Machine, and which is so arranged as to *discharge* itself spontaneously whenever the disturbance in its equilibrium attains a certain intensity. If the movement of the machine be uniform, and other conditions remain the same, the discharge will take place at regular intervals.

more and more irritable, contractions being far more readily excited in it by electrical or other stimulation, in the later than in the earlier months of pregnancy; and at last this irritability seems to reach its *acme*, in virtue of the nutritive changes which have been progressively taking place in it, and to discharge itself in one powerful effort (See § 242). Certain preparatory changes are known to be taking-place in the Uterus itself, during the last two or three weeks of gestation; for its upper part contracts more closely around its contents, as if it were bracing itself up for the coming encounter; whilst there is a greater disposition to relaxation of its lower part, as also in the soft parts surrounding the orifice of the pelvis, so that the whole mass descends. It is well known that there is far less aptitude for dilatation in the os uteri, before this change has taken place; so that premature labours are frequently rendered very difficult and tedious by the resistance which the fœtus encounters from the soft parts, notwithstanding that its smaller size enables it to pass more readily through the pelvic canal.—That the parturient effort, however, is not solely dependent upon the state of development of the uterus, appears from several considerations: and, in the first place, from the very curious fact that, in cases of extra-uterine fœtation, contractions resembling those of labour take place in its walls. In fact, what may be termed the *maturation* not merely of the Uterus, but also of its Embryonic contents, —a condition analogous to that which precedes the dropping of ripe fruit, and which is acquired by the completion of the developmental process,—appears to have more influence in determining the normal parturient effort, than any other cause which can be assigned. The Placenta of the fully-developed fœtus, indeed, is somewhat in the condition of the footstalk of a ripening fruit; that is, having attained its full evolution as an organ of temporary function, its connection tends to become dissevered in virtue of the further changes which take place in itself, quite irrespectively of any external agency.* This is very strikingly evinced by the fact, that when the uterus contains two fœtuses, and one of them is expelled,—either in consequence of impeded development or of disease in itself, or because it has attained its own full term of development (as in cases of superfœtation, § 878),—the other, if its development at this period is far from complete, is often retained, and goes-on to its full term, *its* placenta not being detached in the first parturient effort, because it was not then prepared for the separation. It is obvious that this view affords a rational explanation of the occurrence of uterine action in cases of extra-uterine fœtation; for, if the condition of the placental attachment furnish its exciting cause, it will do so equally, whether the placenta be attached to the lining of the uterus, or to that of the Fallopian tube, or to any other organ. It is an additional indication that the immediate stimulus to the parturient effort of the uterus, is given by some change in the condition of its fœtal connections, that the term of gestation seems capable of being prolonged by peculiarities in the constitution or rate of development of the fœtus, which are derived from the male parent, for

* Such a change may be easily verified in the placenta of many of the lower animals, such as the Cat, in which the fœtal and maternal portions remain more distinct from each other, than they do in the Human female; for these become far more easily separable as the period of parturition draws near, than they are at any previous time.

it was ascertained by the late Earl Spencer,* that of 75 cows in calf by a particular bull, the average period was 288½ days, instead of 280; none of these having gone less than 281 days, and two-fifths of them having exceeded 289 days.†

875. Various states of the constitution, especially that which is designated as 'irritability,' may induce the occurrence of the parturient effort at an earlier period; and this constitutes Premature Delivery, or Abortion, according as the child is, or is not, *viable* (§ 876). There are some women in whom this regularly happens at a certain month, so that it seems to be an action natural to them; but it is always to be prevented, if possible, being injurious alike to the mother and to the child; and this prevention is to be attempted by rest and tranquillity of mind and body, and by a careful avoidance of all the exciting causes which may produce uterine contractions by their operation on the Nervous system (§ 872). Among the causes of Abortion, however, the death of the fœtus, or an abnormal state of the placental structure, is one of the most common; and thus we have another very distinct proof of the influence which the state of the *contents* of the uterus has on the induction of the parturient effort.

876. The question of the *extreme limits* of the period of Gestation, is one of great importance both to the Practitioner and to the Medical Jurist. —In regard to the *shortest* period at which Gestation may terminate, consistently with the *viability* of the Child, there is still a great degree of uncertainty. Most practitioners are of opinion, that it is next to impossible for a fœtus to live and grow to maturity, which has not nearly completed its seventh month; but it is unquestionable that infants born at a much earlier period, have lived for some months, or even to adult age. It is rare in such cases, however, that the date of conception can be fixed with sufficient precision to enable a definite statement to be given. Of the importance of the question, a case which some time since occurred in Scotland affords sufficient proof. A vast amount of contradictory evidence was adduced on this trial; but, on the general rule of accepting positive in preference to negative testimony, it seems

* See Dr. J. C. Hall in "Medical Gazette," May 6, 1842.

† The very ingenious doctrine has been propounded by Dr. Tyler Smith ("Parturition, and the Principles and Practice of Obstetrics," London, 1849), that the exciting cause of parturition is to be found in the recurrence of the periodical excitement of the ovary, acting by reflexion on the uterus through the spinal system of nerves, the ovarian nerves being the *excitors*, and the uterine the *motors*, this excitement continuing during the entire period of gestation, and giving a special tendency to abortion at each return, and acting with such potency at the eleventh recurrence, as then to induce the parturient effort. He assigns no other cause, however, why this eleventh recurrence should be so much more effectual than the rest, than that by this time there is a much greater aptitude to contraction in the uterus itself, and an increased readiness to be thrown off on the part of the placenta, —conditions which seem to the Author to be in themselves adequate to account for the result. Dr Tyler Smith's hypothesis is distinctly negatived by the following facts:—1. The period of gestation, although *commonly* a multiple of the menstrual interval, is by no means *constantly* so; the former often remaining normal, when the latter is shorter or longer than usual. 2 Parturient efforts take place in the uterus, notwithstanding the previous removal of the lower part of the spinal cord. 3 The removal of the ovaries in the later part of gestation does not interpose the least check to the parturient action, as Prof. Simpson of Edinburgh has experimentally ascertained.—The Author considers himself fully justified, therefore, in asserting that this hypothesis does not possess the slightest claim to be entertained as even a *possible* one; and would refer, for a more detailed examination of it, to the "Brit. and For. Med.-Chir. Review," vol iv. p. 1.

that we ought to consider it possible that a child may live for some months, which has been born at the conclusion of 24 weeks of gestation. In the case in question, the Presbytery decided in favour of the legitimacy of an infant born alive within 25 weeks after marriage.* A very interesting case is on record,† in which the mother (who had borne five children) was confident that her period of gestation was less than 19 weeks; the facts stated respecting the development of the child are necessarily very imperfect, as it was important to avoid exposing his body, in order that his temperature might be kept-up; but three weeks after his birth, he was only 13 inches in length, and his weight was no more than 29 oz. At that time, according to the calculation of the mother, he might be regarded as corresponding with an infant of 22 weeks or 5 months; but the length and weight were greater than is usual at that period, and he must probably have been born at about the 25th week. It is an interesting feature in this case, that the calorific power of the infant was so low, that artificial heat was constantly needed to sustain it; but that under the influence of heat of the fire he evidently became weaker, whilst the warmth of a person in bed rendered him lively and comparatively strong. During the first week, it was extremely difficult to get him to swallow; and it was nearly a month before he could suck. At the time of the report, he was four months old, and his health appeared very good.—Another case of very early viability has been more recently put on record by Mr. Dodd:‡ in this, as in the former instance, the determination of the child's age rests chiefly on the opinion of the mother; but there appears no reason for suspecting any fallacy. The child seems to have been born at the 26th or 27th week of gestation, and having been placed under judicious management, it has thriven well.—One of the most satisfactory cases on record, is that detailed by Dr. Outrepont§ (Professor of Obstetrics at Wurtzburgh), and stated by Dr. Christison in his evidence on the case first alluded-to. The evidence is as complete as it is possible to be in any case of the kind; being derived not only from the date assigned by the mother to her conception, but also from the structure and history of the child. The gestation could have only lasted 27 weeks, and was very probably less. The length of the child was 13½ inches, and its weight was 24 oz. Its development was altogether slow; and at the age of eleven years, the child seemed no more advanced in body or mind, than most other lads of seven years old. In this last point, there is a very striking correspondence with the results of other observations upon premature children, made at an earlier age.—A very remarkable case has been since put on record by Dr Barker of Dumfries,‖ in which the child is affirmed to have been born on the 158th day of gestation, or in the middle of the *twenty-third* week after intercourse. In size, weight, and grade of development were conformable to the asserted period: for it weighed only 16 oz., and measured 11 inches; it had only rudimentary nails, and scarcely any hair except a little of reddish colour on the back of the head; the eyelids were closed,

* "Report of Proceedings against the Rev. Fergus Jardine," Edinburgh, 1839.
† "Edinb. Med. and Surg. Journal," vol. xi.
‡ "Provincial Medical and Surgical Journal," vol. ii. p. 474.
§ "Henke's Zeitschrift," band vi.
‖ "Medical Times," Sept. 7, and Oct. 12, 1850.

and did not open until the second day; the skin was shrivelled. When born it was wrapped-up in a box and placed before the fire. The child did not suck properly until after the lapse of a month, and did not walk until she was nineteen months old. Three years and a half afterwards, this child was in a thriving state, and very healthy, but of small make; she then weighed 29½ lbs.

877. A like uncertainty exists with regard to the degree of *protraction* of which the ordinary duration of Gestation is capable.—Many obstetric practitioners, whose experience should give much weight to their opinion, maintain that the regular period of 40 weeks is never extended by more than two or three days; whilst, on the other hand, there are numerous cases on record, which, if testimony is to be believed at all (and in many of these, the character and circumstances of the parties place them above suspicion), furnish ample evidence, that Gestation may be prolonged for at least three weeks beyond the regular term.* The English law fixes no precise limit; and the decisions which have been given in our courts, when questions of this kind have been raised, have been mostly formed upon the collateral circumstances. The law of France provides that the legitimacy of a child born within 300 days after the death or departure of the husband shall not be questioned; and a child born after more than 300 days is not declared a bastard, but its legitimacy may be contested. By the Scotch law, a child is not declared a bastard, unless born after the tenth month from the death or departure of the husband.—Very important evidence on this subject is afforded by investigations on the lower animals, which are free from many sources of fallacy that attend human testimony. The observations of Tessier, which were continued during a period of forty years, with every precaution against inaccuracy, have furnished a body of results which seems quite decisive. In the Cow, the ordinary period of gestation is about the same as in the Human female; but out of 577 individuals, no less than 20 calved beyond the 298th day, and of these, some went-on to the 321st, making an excess of nearly six weeks, or about *one-seventh* of the entire period. Of 447 Mares, whose natural period of gestation is about 335 days, 42 foaled between the 359th and the 419th days, the greatest protraction being thus 84 days, or just *one-fourth* of the usual term. Of 912 Sheep, whose natural period is about 151 days, 96 yeaned beyond the 153rd day; and of these, 7 went-on until the 157th day, making an excess of 6 days. Of 161 Rabbits, whose natural period is about 30 days, no fewer than 25 littered between the 32nd and the 35th; the greatest protraction was here *one-sixth* of the whole period, and the proportion in which there was a manifest prolongation was also nearly one-sixth of the total number of individuals. In the incubation of the common Hen, the duration of which must be entirely determined by the rate of embryonic development, Tessier found that there was not unfrequently a prolongation to the amount of three days, or *one-seventh* of the whole period.—In regard to Cows, the observations of Tessier have been confirmed by those of Earl Spencer, who has published† a table of the period of gestation as observed in 764 individuals; he considers the average period to be 284 or 285 days; but

* A good collection of such cases will be found in Dr. Montgomery's excellent work on the "Signs of Pregnancy," and in Dr. A. Taylor's "Medical Jurisprudence."

† "Journal of the English Agricultural Society," 1839.

no fewer than 310 calved after the 285th day; and of these, 3 went-on to the 306th day, and 1 to the 313th. It is curious that among the calves born between the 290th and 300th days, there was a decided preponderance of males,—these being 74, to 32 females; whilst all of those born after the 300th day were females. The additional series of observations subsequently made by Earl Spencer, in regard to the constant protraction of the period in 75 cows in calf by a particular bull, has been already noticed (§ 874).—Another series of observations has been published by Mr. C. N. Bement of Albany, U.S.,* who has recorded the period of gestation of 62 Cows. The longest period was 336 days; the shortest, 213 days. The average period for male calves was 288 days, and for females 282 days.—On the whole it may be considered, that in regard to the Human female, the French law is a very reasonable one, there being quite sufficient analogical evidence to support the assertions of females of good character, having no motive to deceive, which lead to the conclusion that a protraction of at least four weeks is quite possible, and that a protraction of six weeks is scarcely to be denied.†

878. There is another question regarding the function of the Female in the Reproductive act, which is of great interest in a scientific point of view, and which may become of importance in Juridical inquiries, namely, the possibility of *Superfœtation*, that is, of two distinct conceptions at an interval of greater or less duration; so that two fœtuses of different ages, the offspring perhaps of different parents, may exist in the uterus at the same time.—The simplest case of Superfœtation, the frequent occurrence of which places it beyond reasonable doubt, is that in which a female has intercourse on the same day with two males of different complexions, and bears twins at the full time; the two infants resembling the two parents respectively. Thus, in the slave-states of America, it is not uncommon for a black woman to bear at the same time a black and a mulatto child; the former being the offspring of her black husband, and the latter of her white paramour. The converse has occasionally, though less frequently, occurred: a white woman bearing at the same time a white and a mulatto child. There is no difficulty in accounting for such facts, when it is remembered that nothing has occurred to prevent the uterus and ovaria from being as ready for the second conception as for the first; since the orifice of the former is not yet closed up; and, at the time when one ovum is matured for fecundation, there are usually more in nearly the same condition.—But it is not easy thus to account for the birth of two children, each apparently mature, at an interval of five or six months; since it might have been supposed that the uterus was so completely occupied with the first ovum, as not to allow of the transmission of the seminal fluid necessary for the fecundation of the second. In cases where two children have been *produced* at the same time, one of which was fully-formed, whilst the other was small and seemingly premature, there is no occasion whatever to imagine that the two were *conceived* at different periods; since the smaller fœtus may have been 'blighted,' and its development retarded, as not unfrequently happens

* "American Journal of the Medical Sciences," October, 1845.

† See especially two cases, 183 and 184, detailed by Dr. Murphy in his "Report of the Obstetric Practice of University College Hospital" for 1844, and another case since published by him in the "Medical Gazette" for 1849, vol. xlviii. p. 683.

in other cases. Nor is it necessary to infer the occurrence of superfœtation in every case, in which a living child has been produced a month or two after the birth of another; since the latter may have been somewhat premature, whilst the former has been carried to the full term. But such a difference can scarcely be, at the most, more than $2\frac{1}{2}$ or 3 months; and there are several cases now on record, in which the interval was from 110 to 170 days, whilst neither of the children presented any indication of being otherwise than mature.*

879. Whatever be the precise nature and history of the Fecundating process, there can be no doubt that the properties of the Germ depend upon conditions, both material and dynamical, supplied by *both* Parents. This is most obviously shown by the *fusion* of the characters of the parents, which is exhibited by *hybrids* between distinct species or strongly-marked varieties among the lower animals, such as the Horse and Ass, the Lion and Tiger, or the various breeds of Dogs; or in the offspring of parents belonging to two strongly-contrasted Races of Men, such as the European on the one hand, and the Negro or American Indian on the other.—It has long been a prevalent idea, that certain parts of the organism of the offspring are derived from the male, and certain other parts from the female parent; and although no universal rule can be laid down upon this point, yet the independent observations which have been made by numerous practical 'breeders' of domestic animals (both mammals and birds), seem to establish that such a *tendency* has a real existence; the characters of the *Animal* portion of the fabric being especially (but not exclusively) derived from the *male* parent, and those of the *Organic* apparatus being in like manner derived from the *female* parent. The former will be chiefly manifested in the external appearance, in the general configuration of the head and limbs, in the organs of the senses (including the skin), and in the locomotive apparatus; whilst the latter show themselves in the size of the body (which is primarily determined by the development of the viscera contained in the trunk), and in the mode in which the vital functions are performed. Thus the *mule*, which is the produce of the male ass and the mare, is essentially a *modified ass*, having the general configuration of its sire (slightly varied by equine peculiarities), but having the rounder trunk and larger size of its dam; on the other hand, the *hinny*, which is the offspring of the stallion and the she-ass, is essentially a *modified horse*, having the general configuration of the horse (though with a slight admixture of asinine features), but being a much smaller animal than its sire, and thus approaching its dam in size, as well as in the comparative narrowness of its trunk. The influence of the female on the general 'constitution,' and especially on the fattening, milking, and breeding qualities of the offspring, is asserted to be proved by the history of several races of sheep and cattle, which have been most distinguished in these respects.†—But however *general* this rule may prove to be as regards the lower animals, it is by no means *universal;* for instances are by no

* See the Article 'Superfœtation,' in Dr Beck's "Elements of Medical Jurisprudence."

† See Walker "On Intermarriage;" Orton on 'The Physiology of Breeding,' in the "Newcastle Chronicle," March 10, 1854, and Dr. Alex. Harvey 'On the Relative Influence of the Male and Female Parents in the Reproduction of the Animal Species,' in "Edinb. Monthly Journ.," Aug. 1854.

means unfrequent, in which the multiple progeny of one conception divide between them the characters of the parents in very different modes. Thus, in a case in which a Setter bitch, having been 'lined' by a Pointer, bore three pups, two of these pups seemed exclusively to resemble the father, appearing to be perfect Pointers in configuration, and growing-up with the habits of that race; whilst the third seemed equally to resemble its mother, being apparently a true Setter both in structure and instinct. Yet notwithstanding this apparent restriction, it subsequently appeared that the pointer-pups must have had something of the setter in their constitution, and the setter-pup something of the pointer. For one of the Pointer-pups (a male) having been matched at the proper age with a Pointer-bitch of pure breed, one of the pups borne by the latter was a *true setter*, exactly resembling its paternal grandmother, and another was *setter-marked*, and the Setter-pup (a female) having been lined by a Setter-dog of pure breed, there were among its litter of pups two *pointers* resembling their maternal grandfather.—The same variety presents itself to even a greater degree in the Human species. For in almost every large family (and sometimes even where there are no more than two children*), it will be observed that the likeness to the father predominates in some of the children, and the resemblance to the mother in others. Still it is rare to meet with instances in which *some* distinctive traits of *both* parents may not be traced in the offspring; these traits often showing themselves in peculiarities of manner and gesture, in tendencies of thought or feeling, in proneness to particular constitutional disorders, &c., even where there is no personal resemblance, and where there has been no possibility that these peculiarities should have been gained by imitation. And even when they are overborne, as it were, in the immediate progeny, by the stronger influence derived from the other side, they will often reappear in a subsequent generation (as in the case just cited), constituting the phenomenon known as *Atavism*.

880. The influence of both Parents on the constitution of the Offspring, is strikingly manifested, not merely in the admixture of their characters normally displayed by the latter, but also in the tendency to the *hereditary transmission* of perverted modes of functional activity which may have been habitual to either. The diseases which are usually considered to be most prone thus to reappear in successive generations, are Scrofula, Gout, Syphilis, and Insanity; but it can scarcely be doubted that many others might be added to this list.† The predisposition may have been *congenital* on the part of the parents, or it may have been *acquired* by themselves; and in no case is this more obvious, than in the influence of Alcoholic excesses on the part of one or both parents, in producing Idiocy, a predisposition to Insanity, or weakness and instability of Mind, in the children, this being especially the case where both parents have thus

* One of the most remarkable cases of this kind known to the Author, is that of two Sisters, who seem to resemble each other in no one point of configuration or mental character; but of whom one bears a most striking resemblance, both in person and in mind, to her Father; whilst the other no less strikingly resembles her Mother. The only peculiarities which at all indicate their relationship, are a gouty diathesis which they both inherit from their father, and an idiosyncrasy in regard to opium, of which neither is able to take even a small dose (in any form whatever) without violent vomiting.

† See the very interesting and suggestive Chapter 'On Hereditary Disease,' in Sir H. Holland's "Medical Notes and Reflections."

transgressed. Thus out of 359 Idiots, the condition of whose progenitors could be ascertained, it was found that no fewer than 99 were the children of absolute drunkards; and there was reason to believe that a large proportion of the parents of the remainder were more or less intemperate, only about a quarter of the whole number of idiots having been found to be the children of parents who were known to be temperate.* And it is perfectly well known to those who are conversant with Insanity, that of all the 'predisposing causes' of that disorder, habits of intemperance on the part of either or both parents are among the most frequent.—The intensification which almost any kind of perversion of Nutrition derives from being common to *both* parents, is most remarkably evinced by the lamentable results which too frequently accrue from the marriage of individuals nearly related to each other, and partaking of the same 'taint.' Such results must have fallen within the knowledge of almost every one possessing an extended field of observation; but they are brought-out with fearful vividness by the unerring test of properly-collected Statistics. For out of the 359 idiots just referred-to, 17 were *known* to have been the children of parents nearly related by blood; and this relationship was *suspected* to have existed in several other cases, in which positive information could not be obtained. On examining into the history of the 17 families to which these individuals belonged, it was found that they had consisted, in all, of 95 children; that of these, no fewer than 44 were idiotic, 12 others were scrofulous and puny, 1 was deaf, and 1 was a dwarf. In some of these families, all the children were either idiotic, or very scrofulous and puny; in one family of 8 children, 5 were idiotic.†—But it does not seem requisite for the production of very imperfect offspring from the intermarriage of near relations, that any decided 'taint' should exist in the parents; for the Author's own observations and enquiries lead him to conclude that the same danger results, when there is any strong personal or mental 'idiosyncrasy,' such as is often seen to run through the members (both male and female) of a particular family, causing them to be at once recognized as belonging to it, by those who have been familiar with other members.‡ This liability probably does not exist to nearly the same degree, where the parents, although nearly related, differ widely in physical and in psychical characters, through the predominance of elements which have been introduced by *their* non-related parents; as, for example, when a man who strongly resembles his *father* rather than his mother, marries the daughter of his *mother's* brother, who, on her part, resembles her own *mother* rather than her father. But the case previously cited (§ 879) gives warning that even here the 'family idiosyncrasy' may exist in a powerful degree, though in a latent form, and may seriously affect the constitution of the offspring. It is quite as common to meet

* See Dr. Howe's "Report on Idiocy to the Legislature of Massachusetts," 1848.

† See Dr. Howe's Report, p. 90. An abstract of this Report is given in the "Amer. Journ. of Med. Sci.," April, 1849.

‡ A most lamentable instance of this kind, which happened some years ago, in a family well known to the Author, was the occasion of his first directing his attention specially to this point. Two first-cousins, possessing a strong 'family idiosyncrasy,' but no definite 'taint,' having married, four children were born, each of which was distinguished by some marked defect of organization or perversion of function; one being deaf and dumb, another scrofulous, a third idiotic, and the fourth epileptic.

with Atavism in the transmission of hereditary disease, as in the reproduction of 'family likeness.'

881. Attention has recently been directed to a very curious class of phenomena, which show that where the mother has previously borne offspring, the influence of *its* father may be impressed on her progeny afterwards begotten by a different parent: as in the well-known case of the transmission of Quagga-marks to a succession of colts, both whose parents were of the species Horse, the mare having been once impregnated by a Quagga male,* and in the not unfrequent occurrence of a similar phenomenon in the Human species, as when a widow who marries a second time, bears children strongly resembling her first husband. Some of these cases appear referable to the strong mental impression left by the first male parent upon the female: but there are others which seem to render it more likely, that the blood of the female has imbibed from that of the fœtus, through the placental circulation, some of the attributes which the latter has derived from its male parent; and that the female may communicate these, with those proper to herself, to the subsequent offspring of a different male parentage.†—This idea is borne-out by a great number of important facts; and it serves to explain the circumstance well known to practitioners, that secondary syphilis will often appear in a female during gestation or after parturition, who has never had primary symptoms, whilst the father of the child shows no recent syphilitic disorder. For if *he* have communicated a syphilitic taint to the fœtus, the mother may become inoculated with it through her offspring, in the manner just described. As this is a point of great practical importance, it may be hoped that those who have the opportunity of bringing observation to bear upon it, will not omit to do so.

882. There seems good reason to believe, moreover, that the attributes of the Germ are in great degree dependent, not merely upon the *habitual* conditions of the Parents which have furnished its original components, but even upon the condition in which those parents may be at the time of sexual congress. Of this we have a remarkable proof in the phenomenon well known to breeders of animals, that a strong mental impression made upon the female by a particular male, will give the offspring a resemblance to him, even though she has had no sexual intercourse with him,‡ a circumstance for which there is no difficulty in accounting, on the hypothesis already put-forth regarding the dynamical relation of Mental states to the Organic processes (Chap. xv.). And there is no improbability, therefore, in the idea that the offspring of parents ordinarily healthy and temperate, but begotten in a fit of intoxication on both sides, would be likely to suffer permanently from the abrogation of the reason, which they have temporarily brought upon themselves.§—On the whole, then, we seem entitled to conclude, that the attributes of the embryo will be influenced in a most important degree by the entire condition (as relates both to the organic and the psychical life) of both parents

* "Philosophical Transactions," 1821.

† See an interesting discussion of this question, by Dr. Alex. Harvey, in the "Edinb. Monthly Journ.," Oct., 1849, and Oct. and Nov., 1850; and in his pamphlet "On a Remarkable Effect of Cross-breeding," Edinb., 1851.

‡ See Harvey, loc. cit.

§ See a case of this kind related by Mr. G. Combe in the "Phrenological Journal," vol. viii. p. 471.

at the time of the sexual congress; and it is probably on account of the perpetual changes taking-place in the bodily and mental state of each individual (his condition at any one time being the general resultant of all those changes), that we almost constantly witness marked differences between children born at successive intervals, however strong may be the 'family likeness' among them; whilst the resemblance between twins is almost invariably much closer.*

883. When it is borne in mind, that during the entire period of gestation, the Embryo is deriving its nutriment exclusively from the blood of the Mother, and that the condition of this fluid in relation to her own processes of Nutrition and Secretion, is subject to a very marked influence from her own mental states (Chap. xv.), it cannot fairly be thought improbable, that the developmental processes of the Embryo should be powerfully affected by strong Emotional excitement on her part. Among the facts of this class, there is, perhaps, none more striking than that quoted by Dr. A. Combe† from Baron Percy, as having occurred after the siege of Landau in 1793. In addition to a violent cannonading, which kept the women for some time in a constant state of alarm, the arsenal blew-up with a terrific explosion, which few could hear with unshaken nerves. Out of 92 children born in that district within a few months afterwards, Baron Percy states that 16 died at the instant of birth; 33 languished for from 8 to 10 months, and then died; 8 became idiotic, and died before the age of 5 years; and 2 came into the world with numerous fractures of the bones of the limbs, probably caused by irregular uterine contractions. Here, then, is a total of 59 children out of 92, or within a trifle of 2 out of every 3, actually killed through the medium of the Mother's alarm and the natural consequences upon her own organization; an experiment (for such it is to the Physiologist) upon too large a scale for its results to be set down as mere 'coincidences.'—No soundly-judging Physiologist of the present day is likely to fall into the popular error, of supposing that 'marks' upon the Infant are to be referred to some *transient* though strong impression upon the imagination of the Mother; but there appear to be a sufficient number of facts on record, to prove that *habitual* mental conditions on the part of the Mother *may* have influence enough, at an early period of gestation, to produce evident bodily deformity, or peculiar tendencies of the mind (§ 838). The error of the vulgar notion on this subject, lies in supposing that *a sudden fright, speedily forgotten*, can exert such a continual influence on the nutrition of the Embryo, as to occasion any personal peculiarity.‡ The view here stated, is one which ought to

* Where twins are very unlike one another, it will usually be found that the dissimilarity is due to the predominance of the characters of the father in one, and of those of the mother in the other: as in the case of the Pointer and Setter previously cited (§ 879).

† "On the Management of Infancy," p. 76.

‡ For some valuable observations on this subject, see Montgomery "On the Signs of Pregnancy." Numerous cases were recorded a few years since (especially in the "Lancet" and "Provincial Medical Journal"), in which malformations in the Infant appeared distinctly traceable to strong impressions made on the mind of the Mother some months previously to parturition; these impressions having been persistent during the remaining period of pregnancy, and giving rise to a full expectation on the part of the Mother, that the child would be affected in the particular manner which actually occurred. Of one very striking case of this kind, the Author is personally cognizant, it having occurred in the family of a near connection of his own.

have great weight, in making manifest the importance of careful management of the health of the Mother, both corporeal and mental, during the period of pregnancy; since the ultimate constitution of the offspring so much depends upon the influences then operating upon its most impressible structure.

4.—*Development of the Embryo.*

884. The history of the evolution of the Germ, from its first appearance as *a single cell* lying in the midst of the yolk, to the time when it presents the form and structure characteristic of its parent-species, and is capable of maintaining an independent existence,—including the details of the progressive development of each separate organ, from its first appearance as an aggregation of simple cells formed by the duplicative subdivision of the primordial vesicle, to that stage of completeness in which it is able to bear a part in the vital economy of the new being,—and embracing, also, the succession of changes in the provisions for the nutrition of the embryo in the successive phases of its existence, and the adaptations of its general organization to each respectively,—constitutes one of the most interesting departments of Physiological Science, and one which has of late years received a peculiar degree of attention. It is a branch of the inquiry, however, which has, and seems likely to have, less *practical* bearing than any other; for neither as regards the preservation of the body in health, nor its restoration from disease, is it easy to see what direct benefit the most exact knowledge of Embryonic Development is likely to afford. The chief subject on which it throws light, is that of Congenital Malformations and Deficiencies, many of which are now distinctly traceable to *arrest* or *irregularity* of the developmental processes; some of them, indeed, to *excess* (§ 355). For these reasons, the topic before us will be passed-over much more lightly in the present Treatise, than its scientific importance might seem to demand; and all that will be here attempted, will be a mere sketch of the mode in which the evolution of the germ takes place, this being followed in the first instance as a whole, whilst its principal organs will be afterwards separately considered as they successively present themselves.—This sketch, however, will serve to convey an idea of the nature of the process, and to illustrate its conformity in Man to that great law of progress *from the general to the special*, which is equally manifested in the development of every other organized being. (See Princ. of Comp. Phys., Chap. I.)

885. When we first discern the primordial cell which is to evolve itself into the Human organism, we can trace nothing that essentially distinguishes it from that which might give origin to *any* other form of organic structure, either Vegetable or Animal; its condition, in fact, being permanently represented by the humblest single-celled Plants and Animals. The earliest stage of its development consists in simple multiplication by 'duplicative subdivision' (Princ. of Gen. Phys.), so that a mass of cells comes to be produced, amidst the several components of which no difference can be traced; and this also finds its parallel among the simpler organisms of both kingdoms. Soon, however, this *homogeneous* condition gives rise to a *heterogeneous* one; the further changes which different parts of this mass undergo, not being of the same

uniform character, so that a marking-out of *organs*, or instrumental parts adapted for different purposes in the economy, comes to be discernible. The organs, however, whose distinctness first becomes apparent, are not (for the most part) those which we trace in the completed structure, but have a merely temporary character, being evolved either as a sort of scaffolding or frame-work for the building-up of the more permanent parts, or with a view to the nutrition of the embryo during the evolution of these. Although the first indications of heterogeneousness in the germinal mass are of nearly the same kind in all animals,—consisting in the formation of a *blastodermic membrane* (composed, however, of nothing else than layers of cells) upon its exterior, which serves as a sort of temporary stomach, whilst a large part of the included mass undergoes liquefaction, and serves as the nutrient material for the tissues which are to be evolved from it,—yet indications are very speedily manifested, of the *primary division* of the Animal Kingdom of which the new being is a member, thus, in the case of the Human embryo, as of that of all Vertebrated animals, the first outline of the permanent organization is shown in the 'primitive trace' which marks-out the line of the vertebral column (Plate II., Fig. 11); and in this we very soon discern the foundations of the separate vertebræ (Fig. 12, c). But there is nothing at this period to distinguish the germ of Man from that of *any other* Vertebrated animal, this early part of the developmental process being carried-on upon the same plan in every member of that sub-kingdom; and it is not until we meet with indications of one of the plans which are peculiar to the respective classes of that sub-kingdom, that we can discover whether the germ in course of evolution is to become a Mammal, Bird, Reptile, or Fish. So, even when it has been recognized as belonging to the Mammalian class, there is at first nothing to distinguish it from that of any other Mammal; and it is only with the advance of the developmental process, that indications successively present themselves, which enable us to distinguish, one after another, the characters of the order, the family, the genus, the species, the variety, the sex, and the individual,—*the more special features progressively evolving themselves out of the more general*, which is the expression of the law of development common to all Organized beings. (See PRINC. OF COMP. PHYS., Chap. xv.)

886. With this progressive alteration in the condition of the embryo itself, a very remarkable series of alterations is proceeding, *pari passu*, in the mode in which it is supplied with nutrient material, and in the provisions for the aeration of its circulating fluid.—The first evolution of the germ takes-place entirely at the expense of the *yolk;* of which, however, the store contained in the Mammalian ovum is very small. The whole of this is very speedily incorporated in the substance of the germ, by the peculiar process to be presently described; and there is no residual store of 'food-yolk,' such as that which, in the Bird, serves for the nutrition of the embryo during the whole remainder of the developmental process, by being gradually absorbed into the substance of the blastodermic membrane, and there converted into blood. The Mammalian ovum, however, from the time it reaches the Uterus, is furnished with a new supply of nourishment, in the fluid secreted by

the Decidual membrane (§ 863); and for the absorption of this, it is particularly adapted by the villosities which develope themselves from its own external envelope. These, at first entirely destitute of blood-vessels, are subsequently penetrated at a certain part of the surface, by the fœtal capillaries brought to them by an organ, the *Allantois*, which is developed in Birds as the temporary instrument of respiration; and thus is originated the *fœtal* portion of the Placenta, of whose formation an account will be presently given (§ 893). From the time that this organ is completed, up to the birth of the Infant, the embryo draws its nutrient materials direct from the maternal blood, though not receiving that blood *as such* into its own organism; and it is through the same medium that the aeration of its own blood is effected, its pulmonary apparatus being as yet inoperative. Its circulating system, arranged in accordance with these requirements, presents many peculiarities which mark its fœtal character; and the alteration in the course of the blood, which takes-place as soon as the respiratory organs come into play, constitutes the essential difference between intra-uterine and extra-uterine life. If, as sometimes happens, the lungs of the new-born infant expand but imperfectly or scarcely at all, the circulation continues to be carried on, in a greater or less degree, upon its intra-uterine plan; and this, when the placenta is no longer capable of supplying the needed aeration, is incompatible with the persistence of life.

887. Our knowledge of the first stages of the developmental process in the Mammalian ovum, is in many respects incomplete, and it is requisite to interpret what has been obscurely seen in the ova of this class, by the clearer views derived from observation of those of the lower animals.*—As already stated (§ 861), the germinal vesicle disappears at or about the time of fecundation; but its disappearance is not a result of fecundation, since it also takes-place in the unimpregnated egg, in consequence (it may be presumed) of the completion of its term of life, and of those operations which it was developed to perform. Its place is seen to be occupied, at an early period after fecundation, by a new and peculiar cell, the origin of which is obscure, but the destination of which is most important; for it is by the 'duplicative subdivision' of this cell, first into 2, then into 4, then into 8, and so on, and by the metamorphoses which its progeny undergo, that the whole embryonic fabric is gradually evolved. Hence this cell may be termed the *embryo-cell*.† At the same time, a peculiar change begins to take place in the yolk, the whole sphere of which is first marked-out by a furrow into two hemispheres, and is at last completely divided by the extension of this fission to the centre; each half is again furrowed and then cleft in the same manner, and thus the entire yolk is broken

* The researches of Kolliker ("Muller's Archiv," 1843, p. 68) and Bagge ("De Evolut. Strongyli et Ascarid., Diss. Inaug," 1841) on the ova of *Entozoa*, those of Mr Newport ("Philos. Transact.," 1851) on the ova of *Batrachia*, and those of Bisch ff ("Entwickelungsgeschichte des Hunde-eies," 1845) on the ova of the *Bitch*, are among the most valuable which we at present possess.

† The embryo-cell has not yet been clearly made-out in the Mammalian ovum; but from the conformity of the subsequent appearances to those which are seen in the ova of the lower animals, there is every reason to believe that the formation of either a complete cell, or of a nucleus having the same essential endowments, is a preliminary to the cleavage of the yolk.

up into a mass of segments (Fig. 128). This 'segmentation' takes place *pari passu* with the multiplication of the embryo-cells, each of

Fig. 128

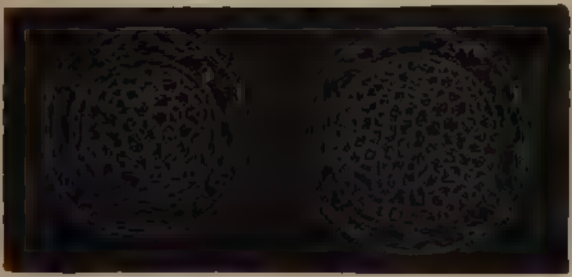
A B C

Progressive stages in the *Segmentation of the Yolk* of the Mammalian Ovum:—A, its first division into two halves; B, subdivision of each half into two; C, further subdivision, producing numerous segments.

which is surrounded by a distinct portion of the yolk; and there seems every probability that it is determined by that multiplication, and that each cell of the pair that is formed by the duplicative subdivision of its predecessor, draws around itself its proper share of the nutritive material. —These changes take place, in the Mammalian Ovum, during its transit along the Fallopian tube to the uterus; so that, by the time of its arrival there, the whole cavity of the *Zona pellucida* is occupied by

Fig. 129.

A B



Later stage in the *Segmentation of the Yolk* of the Mammalian Ovum:—at A is shown the 'mulberry mass' formed by the minute subdivision of the vitelline spheres; at B, a further increase has brought its surface into contact with the vitelline membrane, against which the spherules are flattened.

minute spherules of yolk, each containing a transparent vesicle,* the aggregation of which gives it a mulberry-like aspect (Fig. 129, A); and by a continuance of the same process of subdivision, the component

* It is by no means certain that this vesicle is a true cell in the Mammalian ovum (as it seems clearly to be in the ovum of many of the lower animals), its appearance, when liberated from the yolk-granules which surround it, being rather that of a fat, or oil-globule.

segments becoming more and more minute, the mass comes to present a finely-granular aspect (B).

888. At this stage, it does not appear that the several segments of the yolk have a distinct enveloping membrane; but an envelope is now formed around each of them, converting it into a cell, of which the included vesicle constitutes the nucleus, and of which the portion of the yolk surrounding this forms the contents. This happens first to the peripheral portions of the mass, and as its cells are fully developed, they arrange themselves at the surface of the yolk into a kind of membrane, and at the same time assume a pentagonal or hexagonal shape from mutual pressure, so as to resemble pavement-epithelium (Plate I., Fig. 5). As the globular masses of the interior are gradually converted into cells, they also pass to the surface and accumulate there, thus increasing the thickness of the membrane already formed by the more superficial layer of cells, while the central part of the mass remains occupied only by a clear fluid. By this means the exterior of the yolk is speedily converted into a kind of secondary vesicle, situated within the Zona pellucida, and named by Bischoff the *blastodermic vesicle*. This vesicle, very soon after its formation, presents at one point an opaque, roundish spot (Plate I., Fig. 6), which is produced by an accumulation of cells and nuclei of less transparency than elsewhere; this is termed the *area germinativa*. The wall of the vesicle, which is termed the *germinal membrane*, increases in extent and thickness, by the formation of new cells (whose mode of production has not been clearly made-out); and it subdivides into two layers (Plate I., Fig. 7), which, although both at first composed of cells, soon present distinctive characters, and are concerned in very different ulterior operations. The outer one of these is commonly known as the *serous* layer (Fig. 8); but being the one in whose substance the foundation is laid for the vertebral column and the nervous system, it is sometimes called the *animal* layer. The inner one is usually known as the *mucous* layer (Fig. 9), and being the one chiefly concerned in the formation of the nutritive apparatus, it is sometimes called the *vegetative* layer. This division is at first most evident in the neighbourhood of the area germinativa; but it soon extends from this point, and implicates nearly the whole of the germinal membrane.

889. The Area Germinativa at its first appearance has a rounded form; but it soon loses this, first becoming oval, and then pear-shaped (Plate II., Fig. 11). While this change is taking place in it, there gradually appears in its centre a clear space, termed the *area pellucida* (*a*) and this is bounded externally by a more opaque circle (whose opacity is due to the greater accumulation of cells and nuclei in that part than in the area pellucida), which subsequently becomes the *area vasculosa*. In the formation of these two spaces, both the serous and the mucous layers of the germinal membrane seem to take their share; but the foundation of the embryonic structure, known as the *primitive trace*, is laid in the serous lamina only (Fig. 130). This consists in a shallow groove (*c*), lying between two masses (*b*), known as the *laminæ dorsales*, whose form changes with that of the area pellucida, being at first oval, then pyriform, and at last becoming guitar-shaped; they also rise more and more from the surface of the area pellucida, so as to form two ridges of higher

elevation, with a deeper groove between them; and the summits of these ridges tend to approach each other, and gradually unite, so as to convert the groove into a tube. At the same time, the anterior portion of the groove dilates into three recesses or vesicles (Plate II., Fig. 12, *b*), which indicate the position of the three principal divisions of the Encephalon, afterwards to be developed as the *prosencephalon*, the *mesencephalon*, and the *epencephalon* (§ 909). The most internal parts of these laminæ, bounding the bottom and sides of the groove, appear to furnish the rudiments of the nervous centres which this cranio-vertebral canal is to contain; whilst the outer parts are developed into the rudiments of the vertebral column and cranium. Even before the laminæ dorsales have closed over the primitive groove, a few square-shaped and at first indistinct plates (*c*), which are the rudiments of vertebræ, begin to appear at about the middle of each. The position of the bodies of the vertebræ is indicated at this period, in the embryoes of Birds and Fishes, by a distinct cylindrical rod of nucleated cells, termed the *chorda dorsalis;* and this retains its embryonic type in the Myxinoid Fishes (§ 906). While this is going on, an accumulation of cells takes-place between the two laminæ of the germinal membrane at the 'area vasculosa,' and these cells speedily form themselves into a distinct layer, the *vascular* lamina, in which the first blood-vessels of the embryo are developed, as will be presently described (§ 890). From the dorsal lamina on either side, a prolongation passes outwards and then downwards, forming what is known as the *ventral lamina*, in this are developed the ribs and the transverse processes of the vertebræ; and the two have the same tendency to meet on the median line, and thus to close-in the abdominal cavity, which the dorsal laminæ have to enclose the spinal cord. At the same time, the layers of the germinal membrane which lie beyond the extremities of the embryo, are folded in, so as to make a depression on the yolk; and their folded margins gradually approach one another under the abdomen. The first rudiment of the Intestinal canal presents itself as a channel along the under surface of the embryonic mass, formed by the rising-up of the inner layer of the germinal membrane into a ridge on either side. The two ridges gradually arch-over and meet, so as to form a tube, which is thus (so to speak) pinched-off from the general vitelline sac; and it remains in connection with this, by means of an unclosed portion, which constitutes **the 'vitelline duct' (Figs. 132, 133, 137).**

890. Whilst these new structures are being produced, a very remarkable change is taking-place in that part of the serous lamina which surrounds the area pellucida. This rises up on either side in two folds (Fig. 131, *d*, *e*); and these gradually approach one another (Fig. 132), at last meeting in the space between the general envelope and the embryo, and thus affording an additional investment to the latter (Fig 133). As each fold contains two layers of membrane, the investment thus formed is double; of this, the outer lamina adheres to the general envelope, whilst the inner remains as a distinct sac, to which the name of *Amnion* is given. This takes-place during the third day in the Chick; the date at which it occurs in the Human ovum is difficult to be ascertained, owing to the small number of normal specimens which have come under observation at a sufficiently early stage. During the same period, a very important provision for the future support of the embryo begins to be made, by the

development of Blood-vessels and the formation of Blood. Hitherto, the embryonic structure has been nourished by direct absorption of the ali-

Fig. 130.

Fig. 131.

Fig. 130. Plan of early *Uterine Ovum*. Within the external ring, or zona pellucida, are the serous lamina, a, the yolk, b, and the incipient embryo, c.

Fig. 131. Diagram of Ovum at the commencement of the formation of the *Amnion*: a, chorion; b, yolk-sac; c, embryo; d, and e, folds of the serous layer rising-up to form the amnion.

mentary materials supplied to it by the yolk; but its increasing size, and the necessity for a more free communication between its parts than any structure consisting of cells alone can permit, call for the development of *vessels* through which the nutritious fluid may be conveyed. These vessels are first seen in that part of the Vascular lamina of the germinal membrane, which immediately surrounds the embryo; and they form a network, bounded by a circular channel, which is known under the name of the *Vascular Area* (Plate II., Fig. 13). This gradually extends itself, until the vessels spread over the whole of the membrane that contains the yolk. The first blood-discs appear to be formed from certain cells which are set-free by the liquefaction of others around them to form the vessels (§ 167): and from these, the subsequent blood-discs of the first series are probably generated. This network of blood-vessels serves the purposes of absorbing the nutritious matter of the yolk, and of conveying it towards the embryonic structures which are now in process of rapid development. The first movement of the fluid is *towards* the embryo: and this can be witnessed before any distinct heart is evolved. The same process of absorption from the yolk, and of conversion into blood, probably continues as long as there is any alimentary material left in the sac.

891. The Yolk-sac is entirely separated in the Mammalia, by a constriction of the portion which is continuous with the abdomen of the embryo (Fig. 133, *b*); and it is known from that time under the name of the *Umbilical Vesicle* (Plate I, Fig. 10, *i*). The communication, however, remains open for a time through the 'vitelline duct;' and even after this has been cut-off, the trunks which connect the circulating system of the embryo with that of the vascular area are discernible; these are called *Omphalo-Mesenteric*, *Meseraic*, or *Vitelline* vessels (Figs. 134, 135, *q*, *r*). It was formerly believed that the nutrient matter of the yolk passes directly through the vitelline duct, into the (future) digestive cavity of the embryo, and is from it absorbed into its structure; but there can now be little doubt, that the vitelline vessels are the real agents of its absorption, and that they convey it through the general circulating

system, to the tissues in process of formation. They correspond, in fact, to the Mesenteric veins of Invertebrated animals, which are the sole agents in the absorption of nutriment from their digestive cavity (PRINC. OF COMP. PHYS., Chap. IV.); and the blastodermic vesicle is to be regarded as the temporary stomach of the embryo,—remaining as the permanent stomach in the Radiated tribes.*

892. The formation of the *Heart*, which is the first of the permanent organs of the Embryo that comes into functional activity, takes-place in the substance of the vascular layer, beneath the upper part of the spinal column. Its first rudiment consists of an aggregation of cells, of which the interior break down to form its cavity, whilst the outer remain to constitute its walls. For a long time after it has distinctly commenced pulsating, and is obviously exerting a contractile force, its walls obviously retain the cellular character, and only become muscular by a progressive histological transformation (PRINC. OF GEN. PHYS.). The first appearance of the Heart in the Chick is at about the 27th hour; the time of its formation in Mammalia has not been distinctly ascertained. In its earliest form, it has the same simple character which is presented by the central impelling cavity of the lower Invertebrata; being a mere prolonged canal, which at its posterior extremity receives the veins, and at its anterior sends-forth the arteries. After a short time, however, it becomes bent upon itself (Plate II., Fig. 13, *d*); and it is soon subdivided into three cavities, which exist in all Vertebrata, viz., a simple *auricle* or receiving cavity, a simple *ventricle* or propelling cavity, and a *bulbus arteriosus* at the origin of the aorta. The circulation is at first carried-on exactly upon the plan which is permanently exhibited by Fishes. The Aorta subdivides on either side of the neck into four or five arches (Figs. 134, 135, *e, e', e''*), which are separated by fissures much resembling those forming the entrances to the gill-cavities of Cartilaginous Fishes, and these arches re-unite to form the descending aorta, which transmits branches to all parts of the body.—Such is the first phase or aspect of the Circulating Apparatus, which is *common to all Vertebrata* during the earliest period of their development, and which may, therefore, be considered as its most general form. It remains permanent in the class of Fishes, and in them the vascular system undergoes further development on the same type, a number of minute tufts being sent-forth from each of the arches, which enter the filaments of the gills, and are thus subservient to the aeration of the blood. In higher Vertebrata, however, the plan of

* Previously to the ninth day of incubation (in the Fowl's egg), a series of folds are formed by the lining membrane of the yolk-bag, which project into its cavity; these become gradually deeper and more crowded, as the bag diminishes in size by the absorption of its contents. The vitelline vessels that ramify upon the yolk-bag, send into these folds (or valvulæ conniventes) a series of inosculating loops, which immensely increase the extent of this absorbing apparatus. But these minute vessels are not in immediate contact with the yolk, for there intervenes between them (as was first noticed by Mr. Dalrymple) a layer of nucleated cells, which is easily washed away. (See Dr. Baly's Translation of "Müller's Physiology," pp. 1557–1559.) It was from the colour of these, communicated to the vessels beneath, that Haller termed the latter *vasa lutea*; when the layer is removed, the vessels present their usual colour. There seems good reason to believe that these cells, like those of the Intestinal Villi in the adult (§ 121), are the real agents in the process of absorbing and assimilating the nutritive matter of the yolk; and that they deliver this up to the vessels, by themselves undergoing rupture or dissolution, being replaced by new layers.

the circulation is afterwards entirely changed, as will be presently described, by the formation of new cavities in the heart, and by the production of new vessels, it is incorrect, therefore, to speak of the vascular arches in *their* necks as *branchial* arches, since no branchiæ or gills are ever developed from them. The clefts between them may be very distinctly seen in the Human Fœtus towards the end of the first month; during the second, they usually close-up and disappear.

893. With the evolution of a Circulating apparatus, adapted to absorb nourishment from the store prepared for the use of the Embryo, and to convey it to its different tissues, it becomes necessary that a Respiratory apparatus should also be provided, for depurating the blood from the carbonic acid with which it becomes charged during the course of its circulation. The temporary Respiratory apparatus now to be described, bears a strong resemblance in its own character, and especially in its vascular connections, to the gills of the Mollusca, which are prolongations of the external surface (usually near the termination of the intestinal canal), and which almost invariably receive their vessels from that part of the system. This apparatus, which is termed the *Allantois*, sprouts-forth from the caudal extremity of the embryo, at first as a little mass of cells, which soon exhibits a cavity (probably originating in the liquefaction of the cells of the internal part), so that a vesicle is formed (Figs. 132, 133, *g*), which looks like a diverticulum from the lower part

Fig. 132.

Fig. 133.

Fig. 132. Diagram of an early *Human Ovum*, showing the *Amnion* in process of formation, and the *Allantois* beginning to appear:—*a*, chorion; *b*, vitelline mass surrounded by the blastodermic vesicle; *c*, embryo; *d*, *e*, and *f*, external and internal folds of the serous layer, forming the amnion; *g*, incipient allantois.

Fig. 133. Diagram of a *Human Ovum* in second month, showing the completion of the sac of the *Amnion*, and a further development of the *Allantois*:—*a* 1, smooth portion of chorion; *a* 2, villous portion of chorion; *k*, *k*, elongated villi, beginning to collect into Placenta; *b*, vitelline or umbilical vesicle; *c*, embryo; *f*, amnion (inner layer); *g*, allantois; *h*, outer layer of amnion, coalescing with chorion.

of the digestive cavity. This vesicle, in Birds, soon becomes so large as to extend itself around the whole yolk-sac, intervening between it and the membrane of the shell, and coming through the latter into relation with the external air; but in the embryo of Mammalia, the allantois, being early superseded by another provision for the aeration of the blood, seldom attains any considerable dimensions. Its chief office here is to convey the vessels of the embryo to the chorion; and its extent bears

a pretty close correspondence with the extent of surface, through which the chorion comes into vascular connection with the decidua. Thus, in the Carnivora, whose placenta extends like a band around the whole ovum, the allantois also lines nearly the whole inner surface of the chorion; on the other hand, in Man and the Quadrumana, whose placenta is restricted to one spot, the allantois is small, and conveys the fœtal vessels to one portion only of the chorion. When these vessels have reached the chorion, they ramify in its substance, and send filaments into its villi; and in proportion as these villi form that connection with the uterine structure which has been already described (§§ 866, 867), do the vessels increase in size. They then pass directly from the fœtus to the chorion; and the allantois, being no longer of any use, shrivels up, and remains as a minute vesicle, only to be detected by careful examination. The same thing happens in regard to the umbilical vesicle, from which the entire contents have been by this time withdrawn; and from henceforth the fœtus is completely dependent for the materials of its growth upon the supply it receives through the Placenta, which is conducted to it by the vessels of the umbilical cord. This state of things is represented in Figs. 134, 135, *n n′*, *o o′*. The Allantois is commonly said to give origin to the Urinary Bladder; but this organ is really formed by an enlargement of the upper part of the uro-genital sinus (§ 904), with which the allantois communicates by a duct which gradually shrivels, only a vestige of it remaining permanent, to form the Urachus or suspensory ligament of the bladder, by which this is connected with the umbilicus. Before this takes place, however, the Allantois is the receptacle for the secretion of the Corpora Wolffiana, and also for that of the true Kidneys, when they are formed (§ 902).

894. It will be seen from the succeeding diagram, that the Amnion forms a kind of tubular sheath around the umbilical cord; it is continuous at the umbilicus with the integument of the fœtus; and at the point where the cord enters the placenta, it is reflected over its internal or fœtal surface. It thus forms a shut sac, resembling that of the pleura, arachnoid, &c.; and it contains a fluid, known as the *liquor amnii*, which consists of water holding in solution a small quantity of albumen and saline matter, and resembling, therefore, very diluted serum. During the first two months of gestation, the amnion and the inner lining of the chorion (which is really the reflected layer of the amnion, Fig. 133, *h*, just as the lining of the abdominal cavity is formed by the peritoneum) are separated by a gelatinous-looking substance, which probably aids in the nutrition of the embryo, previously to the formation of the placenta. This is absorbed during the second month; and the amnion is then found immediately beneath the chorion.—In the Umbilical Cord, when it is completely formed, the following parts may be traced. 1. The tubular sheath afforded by the Amnion. 2. The Umbilical Vesicle (Fig. 134, *t*), with its pedicle, or vitelline duct. 3. The Vasa Omphalo-Meseraica (*q*, *r*), or mesenteric vessels of the embryo, by which the yolk was absorbed into its body; these accompany the pedicle. 4. The Urachus, and remains of the Allantois. 5. The Vasa Umbilicalia (*n n*, *o*), which, in the later period of gestation, constitute the chief part of the Cord. These last vessels consist in Man of two arteries and one vein. The arteries are the main branches of the Hypogastric; and they convey to the placenta

the blood which has to be aerated and otherwise revivified, by being brought into relation with that of the mother. The vein returns this to

Fig. 134.

Fig. 135.

Fig. 134. Diagram of the Circulation in the *Human Embryo* and its Appendages, as seen in profile from the right side, at the commencement of the formation of the Placenta.

Fig. 135. The same, as seen from the front:—*a*, venous sinus, receiving all the systemic veins; *b*, right auricle; *b'*, left auricle; *c*, right ventricle; *c'*, left ventricle; *d*, bulbus aorticus, subdividing into *e*, *e'*, *e''*, branchial arches; *f*, *f'*, arterial trunks formed by their confluence; *g*, *g'*, vena azygos superior; *h*, *h'*, confluence of the superior and inferior azygos; *i*, vena cava inferior; *k*, *k'*, vena azygos inferior; *m*, descending aorta; *n*, *n*, umbilical arteries proceeding from it; *o'*, *o*, umbilical veins; *q*, omphalo-mesenteric vein; *r*, omphalo-mesenteric artery, distributed on the walls of the vitelline vesicle *t*; *e*, ductus venosus; *y*, vitelline duct; *z*, chorion.

the fœtus, and discharges a part of it into the Vena Portæ, and a part directly through the Ductus Venosus into the Vena Cava.

895. A change in the type of the Circulating system of the fœtus, from that at first presented by it (§ 892), takes-place at a very early period. At about the 4th week, in the Human Embryo, a septum begins to be formed in the ventricle; and by the end of the 8th week, it is complete. The septum auriculorum is formed at a somewhat later period, and it remains incomplete during the whole of fœtal life; it is partly closed by the valvular fold covering the foramen ovale, which fold is developed in the 3rd month. During the same period, a transformation occurs in the arrangement of the Arterial trunks proceeding from the heart, which ends in their assumption of the form they present until the end of Fœtal life; and this undergoes but a slight alteration, when the plan of the circulation is changed at the moment of the first inspiration. The number of aortic arches on each side, which was five at first, soon becomes reduced in the Mammalia to three, by the obliteration of the

two highest pairs. The 'bulbus aorticus' is subdivided, by the adhesion of its walls at opposite points, into two tubes, of which one becomes the origin of the Aorta and the other that of the Pulmonary Artery; and of the three pairs of (branchial) arches, the highest, being connected with the aortic trunk, contributes to the formation of the Subclavian and Carotid arteries; whilst of the middle pair, the arch on the right side is obliterated, and the other becomes the 'arch of the aorta.' The lowest pair arises from the Pulmonary trunk, and forms the right and left Pulmonary arteries, that on the left side, however, goes-on to join the descending aorta as before, and thus constitutes the Ductus Arteriosus. —A knowledge of these different stages in the development of the Heart and Arterial system enables us to explain many of the malformations which they occasionally present in Man, these being for the most part due to arrest of development, whereby the circulating apparatus is permanently fixed in conditions that are properly characteristic of cold-blooded animals. And it is interesting to remark, too, that the varieties which not unfrequently present themselves in the arrangement of the principal trunks given-off from the Aorta, find their analogues in the arrangements that are normally characteristic of some or other of the Mammalia. (See PRINC. OF COMP. PHYS., §§ 262, 263.)

896. The *Venous* system undergoes changes which are even more remarkable than those of the arterial trunks. In its earliest condition, it has been ascertained by Rathke* to present essentially the same type in the embryoes of all Vertebrated animals; the peculiarities of each group being acquired by a process of subsequent transformation. There is at first a pair of anterior venous trunks (Figs. 134, 135, *g, g'*), receiving the blood from the head, and a pair of posterior trunks (*k, k'*), formed by the confluence of the veins of the trunk, of the Wolffian bodies, &c., the former are persistent as the jugular veins; the latter remain separate in most Fishes, where they are designated the cardinal veins; but in Man (as in warm-blooded Vertebrata generally) they are only represented by the *venæ azygos*, major and minor,† which coalesce into a common trunk for a considerable part of their length. One of the anterior trunks and one of the posterior unite on either side, to form a canal which is known as the Ductus Cuvieri, and the ducts of the two sides coalesce to form a shorter main canal, which enters the auricle, at that time an undivided cavity. This common canal is absorbed into the auricle at an early period, in all Vertebrata above Fishes; and after the septum auricularum is formed, the two Cuvierian ducts separately enter the right auricle. This arrangement is persistent in Birds and the inferior Mammals, in which we find two Venæ Cavæ superiores, entering the right auricle separately; but in the higher Mammalia and in Man, the left duct is obliterated, and the right alone remains as the single Vena Cava superior, a transverse communicating branch being formed, to bring to it the blood of the left side.‡ The double Vena Cava sometimes presents itself

* "Ueber den Bau und die Entwickelung des Venensystems der Wirbelthiere," 1838

† See Muller's "Vergleichende Anatomie der Myxinoiden," Berlin, 1846.

‡ See the elaborate Memoir 'On the Development of the Great Anterior Veins in Man and Mammalia' ("Phil. Trans.," 1850), by Mr J. Marshall, who has further shown that some vestiges of the original arrangement may be traced even in the normal condition of the venous system in the adult.

as a monstrosity in the Human subject. As the anterior extremities are developed, the subclavian veins are formed to return the blood from them; and these discharge themselves into the jugulars. The Omphalo-Mesenteric vein (Fig. 134, *q*), which is another primitive trunk common to all Vertebrata (§ 891), is formed by the confluence of the veins of the yolk bag and intestinal canal, and passes by itself, with the two Cuvierian ducts, into the auricle. The upper part of this remains to constitute the upper part of the Inferior Cava (Figs. 134, 135, *j*), the lower portion of which arises between the Wolffian bodies, and originally enters the omphalo-mesenteric vein above the liver. When the liver is formed, the omphalo-mesenteric vein becomes connected with it, both by afferent and by efferent trunks, the former remaining as the Vena Portæ, and the latter as the Hepatic vein; and after giving-off the former trunks, the omphalo mesenteric vein is itself obliterated, so that all the blood which it conveys passes through the liver. The Inferior Cava, which receives the hepatic vein, is gradually enlarged by the reception of most of the veins from the inferior part of the trunk and the lower extremities, and the vena azygos is reduced in the same proportion; in some rare cases of abnormal formation, however, the vena cava fails to be developed, and then the blood from the lower parts of the body is conveyed to the superior cava through the system of the vena azygos. The Umbilical Vein, which, like the other great venous trunks, is at first double (Figs. 134, 135, *o*, *o'*), is to be regarded as a product of the combination of the veins of the allantois with an anterior vein of the abdominal parietes; it being probably through this latter channel that it comes to discharge itself into the vena portæ, which lies in a part of the body very distant from that at which the allantois was developed. As the omphalo-mesenteric vein diminishes in size, the umbilical veins increase, and coalesce into a single trunk; this then becomes the chief source of supply to the vena portæ, also forming an anastomosis with the inferior cava, which constitutes the Ductus Venosus.

897. The following is the course of the Circulation in the mature Fœtus.—The fluid brought from the Placenta by the umbilical vein is partly conveyed at once to the ascending Cava by means of the ductus venosus, but chiefly flows through the vena portæ into the Liver, whence it reaches the ascending Cava by the hepatic vein. Having thus been transmitted through the great depurating organ, the Placenta, and the great assimilating organ, the Liver,* it is in the condition of arterial blood; but, being mixed in the great vessels with that which has been returned from the trunk and lower extremities, it loses this character in some degree, by the time that it arrives at the Heart. In the right auricle, which it then enters, it would be also mixed with the venous blood brought thither by the descending Cava, were it not that a very curious provision exists, to prevent (in great degree, if not entirely) any such further dilution. The Eustachian valve has been found, by the experiments of Dr. J. Reid,† to serve the purpose of directing the

* It does not seem probable that the depurating action of the Liver can be energetically performed during fœtal life; and its large dimensions and copious supply of blood appear rather to be referable to its function as a *blood making* gland (§ 132).

† "Edinb. Med. and Surg. Journal," vol. xliii., and "Anat., Physiol., and Pathol. Researches," Chap. ix.

arterial blood, which flows upwards from the *ascending* Cava, through the foramen ovale, into the *left* auricle, whence it passes into the *left* ventricle; whilst it also directs the *venous* blood, that has been returned by the *descending* Cava, into the *right* ventricle. When the ventricles contract, the arterial blood which the left contains is propelled into the ascending Aorta, and supplies the branches that proceed to the head and upper extremities, before it undergoes any admixture; whilst of the venous blood contained in the right ventricle, part is transmitted by the Pulmonary artery to the lungs, but another (and probably by far the larger) part finds its way through the Ductus Arteriosus into the descending Aorta, mingling with the arterial current which that vessel previously conveyed, and passing thus to the trunk and lower extremities. Hence the head and superior extremities, whose development is required to be in advance of that of the lower, are supplied with blood nearly as pure as that which returns from the placenta; whilst the rest of the body receives a mixture of this with what has previously circulated through the system; and of this mixture a portion is transmitted to the placenta, to be renovated by coming into relation with the maternal fluid. —At birth, the course of the current is entirely changed by the cessation of the circulation through the Placenta, and by the enormous increase in the quantity transmitted to the Lungs, which takes-place immediately on the first inspiration: the Ductus Venosus and Ductus Arteriosus soon shrivel into ligaments; the Foramen Ovale becomes closed by its valve; and the circulation,

FIG. 136.

Diagram of the *Fœtal Circulation*. 1. The umbilical cord, consisting of the umbilical vein and two umbilical arteries, proceeding from the placenta (2). 3. The umbilical vein dividing into three branches; two (4, 4) to be distributed to the liver, and one (5), the ductus venosus, which enters the inferior vena cava (6). 7. The portal vein, returning the blood from the intestines, and uniting with the right hepatic branch. 8. The right auricle; the course of the blood is denoted by the arrow proceeding from 8, to 9, the left auricle. 10. The left ventricle; the blood following the arrow to the arch of the aorta (11), to be distributed through the branches given off by the arch to the head and upper extremities. The arrows 12 and 13, represent the return of the blood from the head and upper extremities through the jugular and subclavian veins, to the superior vena cava (14), to the right auricle (8), and in the course of the arrow through the right ventricle (15), to the pulmonary artery (16). 17. The ductus arteriosus, which appears to be a proper continuation of the pulmonary artery; the offsets at each side are the right and left pulmonary arteries cut off. The ductus arteriosus joins the descending aorta (18, 18), which divides into the common iliacs, and these into the internal iliacs, which become the umbilical arteries (19) and return the blood along the umbilical cord to the placenta, and the external iliacs (20), which are continued into the lower extremities. The arrows at the termination of these vessels mark the return of the venous blood by the veins to the inferior cava.

which was before carried-on upon the plan of that of the higher Reptiles, now becomes that of the complete Bird or Mammal.* It is by no means unfrequent, however, for some arrest of development to prevent the completion of these changes; and various malformations, involving an imperfect discharge of the function, may hence result.

898. The *Alimentary Canal* has been shown (§ 889) to have its origin in the blastodermic vesicle; being a portion pinched-off (as it were) from that part of it which is just beneath the spinal column of the embryo, whilst the remainder, which is at that time the largest part of it, forms the vitelline or umbilical vesicle. In its earliest form, it is merely a long narrow tube (Fig. 137, *m*), nearly straight, and communicating with the umbilical vesicle (*n*, *n*) at about the middle of its length; thus it may be regarded as composed of the union of two divisions, an upper and a lower. At first, neither mouth nor anus exists; but these are formed early in the second month, if not before. The tube gradually manifests a distinction into its special parts, œsophagus, stomach, small intestine, and large intestine; and the first change in its position occurs in the stomach, which, originally disposed in the line of the body, afterwards takes an oblique direction. The curves of the large and small intestine present themselves at a later period. It is at the lower part of the small intestine, near its termination in the large, that the entrance of the vitelline duct persists, and a remnant of this canal is not unfrequently preserved throughout life, in the form of a small pouch or diverticulum from that part of the intestine.

Fig. 137.

Embryo of *Dog*, 25 days after last copulation.—*a*, *a*, nostrils; *b*, *b*, eyes; *c*, *c*, first visceral arches, forming the lower jaw; *d*, *d*, second visceral arches; *e*, right auricle; *f*, left auricle; *g*, right ventricle; *h*, left ventricle; *i*, aortic bulb; *k*, *k*, liver, between the two lobes of which is seen the divided orifice of the omphalo-mesenteric vein; *l*, stomach; *m*, intestine, communicating with the umbilical vesicle *n*, *n*; *o*, *o*, corpora Wolffiana; *p*, allantois; *q*, *q*, anterior extremities; *r*, *r*, posterior extremities.

* It has been argued by Dr. Peaslee (of Dartmouth College, U. S.), that the above account is incorrect, since the diameter of the Ductus Arteriosus is so small in proportion to that of the Pulmonary arteries, that it can serve no other purpose than that of a 'waste-pipe' to carry-off the superfluous blood which they cannot receive. But he supposes the amount of blood transmitted through these vessels respectively, to be chiefly or entirely determined by their respective diameters; and takes no account of the numerous facts which *prove* that the quantity of blood transmitted to the lungs before birth, is *extremely small* in proportion to that which they receive as soon as the respiratory function is fully established. See his 'Monograph on the Fœtal Circulation,' in "American Medical Monthly," May, 1854.

899. In immediate connection with the intestinal tube, we find the first rudiment of the *Liver*, which is formed by the thickening of the cells in the wall of the canal, at the spot at which the hepatic duct is subsequently to discharge itself. This thickening increases, so as to form a projection upon the exterior of the canal; and soon afterwards the lining membrane of the intestine dips-down into it, so that a kind of cæcum is formed, surrounded by a mass of cells, as shown in Fig. 138. The increase of the organ seems to take-place by a continual new budding-forth of cells from its peripheral portion; and a considerable mass is thus formed, before the cæcum in its interior undergoes any extension by ramifications into it. Gradually, however, the cells of the exterior become metamorphosed into fibrous tissue for the investment of the organ; those of the interior break-down into ducts, which are developed in continuity with the cæcum derived from the intestine, and which are lined by muscular and fibrous tissues developed from the primitive cellular blastema; whilst those which occupy the intervening space, and which form the bulk of the gland, give origin to the proper secreting cells, which are now to come into active operation. As this is going-on, the hepatic mass is gradually removed to a distance from the wall of the alimentary canal; and the cæcum is narrowed and lengthened, so as to become a mere connecting pedicle, forming, in fact, the main trunk of the hepatic duct.—In the Human embryo, the formation of the Liver begins at about the third week of intra-uterine existence; the organ is from the first of very large size, when compared with that of the body; and between the third and the fifth weeks, it is one-half the weight of the entire embryo. It is at that period divided into several lobes. By the third lunar month, the liver extends nearly to the pelvis, and almost fills the abdomen; the right side now begins to gain upon the left; the gall-bladder makes its first appearance at this time. The subsequent changes chiefly consist in the consolidation of the viscus, and the diminution of its proportional size. Up to the period of birth, however, the bulk of the liver, relatively to that of the entire body, is much greater than in the adult; the proportion being as 1 to 18 or 20 in the new-born child, whilst it is about 1 to 36 in the adult; and the difference between the right and left lobes is still inconsiderable. During the first year of extra-uterine life, however, a great change takes place; the right lobe increases a little or remains stationary, whilst the left lobe undergoes an absolute diminution, being reduced nearly one-half; and as, during the same period, the bulk of the rest of the body has been rapidly increasing, the proportion is much more reduced during that period, than in any subsequent one of the same length. According to Meckel, the liver of the newly-born infant weighs one-fourth heavier than that of a child of eight or ten months old; and as the weight of the whole body is more than doubled during the same

FIG. 138.

Origin of the *Liver* from the intestinal wall, in the embryo of the Fowl, on the fourth day of incubation; *a*, heart; *b*, intestine; *c*, everted portion giving origin to liver; *d*, liver; *e*, portion of vitelline vesicle.

time, it is obvious that the change in the proportion of the two must be principally effected at this epoch. The liver seems to be engaged, during fœtal life, in the depuration of the blood (as appears from the accumulation of *meconium*, which is chiefly altered bile, in the intestinal canal at birth); but at the same time it is serving as a blood-making organ (§§ 132, 167), and this is probably its principal function before birth.

900. The general history which has just been given of the development of the Liver, seems equally applicable to the other glands that are evolved from the parietes of the Alimentary canal, such as the *Salivary glands* and *Pancreas;* since they all seem to commence in little masses of cells, formed by an increased development, at certain spots, of the layer of blastema which originally constitutes its wall, and whilst some of these cells give origin to the proper vesicles of each gland, others form its ducts and tubuli by their deliquescence.—The development of the *Spleen* and of the *Supra-Renal, Thymus,* and *Thyroid* bodies, has been already described (§§ 143-147).

901. The *Lungs* are also developed in immediate relation with the upper part of the Alimentary canal, their first rudiments shooting-forth as a pair of bud like processes (Fig 139, *a*) from its œsophageal portion. These were originally described by Von Bar as hollow, and as being in reality *diverticula* from the tube itself. But most later observers agree in stating that the bud-like processes are not at first hollow, but are solid aggregations of cells, formed by a multiplication of the cells constituting the external wall of the alimentary tube, into which its internal tunic is not prolonged. These gradually increase in size, extending downwards by the multiplication of their component cells in that direction; and cavities are formed in them (probably, as in the preceding instances, by the deliquescence or fusion of some of the cells of their interior), which at first communicate with the pharynx by separate apertures, these, however, coalesce into one, as the channels are elongated into tubes, and the pulmonary organs are removed to a distance from their point of exit.—The first appearance of the Lungs, in the Human embryo, takes place at about the 6th week, at which time they are simple elevations of the external layer of the œsophageal wall; from this, however, they are soon removed; each rudimentary lung having its own bronchial tube, connecting it with a trachea common to both (Fig. 139, *b*). Their surface becomes studded with numerous little wart-like projections, which are caused by the formation of corresponding enlargements of their cavity, these enlargements soon become prolonged, and develope corresponding bud-like enlargements from their sides; and in this manner, the form of the organs is gradually changed, a progressive increase in their bulk taking-place from above downwards, in consequence of the extension of the bronchial ramifications of the single tube at the apex. At the same time, however, a corresponding increase in the amount of the parenchy

Fig 139

First appearance of the *Lungs* —*a*, in a *Fowl* at four days, *b*, in a *Fowl* at six days, *c*, termination of bronchus in a very young *Pig*

matous tissue of the lung is taking-place; for this is deposited in all the interstices between the bronchial ramifications, and might be compared with the soil filling-up the spaces amongst the roots of a tree. It is in this parenchyma that the pulmonary vessels are distributed; and the portion of it which extends beyond the terminations of the bronchial tubes, seems to act as the nidus for their further extension. It can be easily shown that, up to a late period of the development of the lungs, the dilated terminations of the bronchi constitute the only air-cells (Fig. 139, *c*); but, as already mentioned, the parenchyma subsequently has additional cavities formed within it.—It is a fact of some interest, as an example of the tendency of certain diseased conditions to produce a return to forms which are natural to the fœtal organism, or which present themselves in other animals, that up to a late period in the development of the Human embryo, the lungs do not nearly fill the cavity of the chest, and the pleura of each side contains a good deal of serous fluid.

902. The embryological development of the *Urinary* organs in Vertebrated animals is a subject of peculiar interest; owing to the correspondence which may be traced between the transitory forms they present in the higher classes, and their permanent condition in the lower. In this respect, there is an evident analogy with the Respiratory system. The first appearance of anything resembling a Urinary apparatus in the Chick, is seen on the second-half of the third day. The form at that time presented by it, is that of a long canal, extending on each side of the spinal column, from the region of the heart, towards the allantois (Fig. 137, *o, o*); on the sides of this are a series of elevations and depressions, indicative of the incipient development of cæca. On the 4th day, the *Corpora Wolffiana*, as they are then termed, are distinctly recognized as composed of a series of cæcal appendages, which are attached along the whole course of the first-mentioned canal, opening into its outer side (Fig. 140, *a*). On the 5th day these appendages are convoluted, and the body which they form acquires increased breadth and thickness; they evidently then possess a secreting function, and the fluid which they separate is poured by their long straight canals (*b, b*) into the cloaca; and between their component shut sacs, numbers of small points appear, which consist of little clusters of convoluted vessels, exactly analogous to the Corpora Malpighiana of the true kidney. These bodies remain as the permanent urinary organs of Fishes; but in the higher Vertebrata they give place to the true Kidneys, the development of which commences in the Chick about the 6th day. These when first seen, are lobulated greyish masses (*c*), which seem to sprout from the outer edges of the Wolffian bodies, but which are really independent formations, springing from a mass of blastema behind them; and as they gradually increase in size and advance in development, the Wolffian bodies retrograde; so that at the end of fœtal life, the only vestige of them is to

FIG. 140.

State of the *Urinary* and *Genital Apparatus* in the early embryo of the Bird:—*a*, corpora Wolffiana; *b, b*, their excretory ducts; *c*, kidneys; *d*, ureter; *e, e*, testes.

be found as a shrunk rudiment, situated (in the male) near the testes, to which their excretory ducts serve as the outlets, becoming the 'vasa deferentia.'—The history of the development of the Urinary organs in the Human embryo, seems to correspond closely with the foregoing. The Wolffian bodies begin to appear towards the end of the first month, and it is in the course of the 7th week, that the true Kidneys first present themselves. When at their greatest development, the Corpora Wolffiana are the most vascular parts of the body next to the liver, four or five branches from the aorta are distributed to each, and two veins are returned from each to the vena cava. The upper arteries and their corresponding veins are afterwards converted into the Renal or emulgent vessels; and the lower into the Spermatic vessels. From the beginning of the 3rd month, a diminution takes-place in the size of the Wolffian bodies, *pari passu* with the increase of the Kidneys; and at the time of birth, scarcely any traces of the former can be found. At the end of the 3rd month, the Kidneys consist of seven or eight lobes, the future pyramids, their excretory ducts still terminate in the canal, the *sinus urogenitalis*, which receives those of the Wolffian bodies (subsequently to become the vasa deferentia), and of the Fallopian tubes;* and this opens, with the rectum, into a sort of *Cloaca*, analogous to that which is permanent in the oviparous Vertebrata. The Kidneys are at this time covered by the Supra-Renal capsules, which equal them in size; about the 6th month, however, these have decreased, whilst the kidneys have increased, so that their proportional weight is as 1 to 2½. At birth, the weight of the Kidneys is about three times that of the Supra-Renal capsules, and they bear to the whole body the proportion of 1 to 80; in the adult, however, they are no more than 1 to 240. The lobulated appearance of the kidney gradually disappears; partly in consequence of the condensation of the areolar tissue which connects its different portions, and partly through the development of additional tubuli in the interstices.—The Urinary Bladder is formed quite independently of the secreting apparatus, being an enlargement of a portion of the *pars urinaria* of the 'uro-genital sinus' (§ 904).

903. The essential parts of the *Generative Apparatus*, namely the Testes in the male, and the Ovaria in the female, are first developed in such immediate proximity with the Corpora Wolffiana (Fig. 140, *e*, *e*), that they have been supposed to sprout-forth from them; this, however, is not really the case, as they have an independent origin in a mass of blastema peculiar to themselves. They make their first appearance in the Chick, as delicate striæ on the Wolffian bodies, about the fourth day, at which period no difference can be detected between the Testes and the Ovaria, which originate in precisely the same manner. In the Human embryo, the rudiments of the sexual organs,—whether testes or ovaria,—first present themselves soon after the kidneys make their appearance, that is, towards the end of the 7th week. They are originally much pro-

* Although it has been usually considered that the Vasa Deferentia of the male and the Fallopian tubes of the female, are homologous organs, yet this does not seem really to be the case, for the former are derived from the excretory ducts of the Wolffian bodies, whilst the latter are independent formations, which are found to co-exist with seminal ducts at an early period of development, alike in male and in female embryos. (See Kobelt, "Der Nebeneierstock des Weibes," Heidelberg, 1847.) The ducts of the Wolffian bodies, although subsequently disappearing in the females of most Mammals, remain permanent as 'Gaertner's canals' in the female Ruminants and Pig.

longed, and seem to consist of a kind of soft, homogeneous blastema, in which the structure characteristic of each organ subsequently developes itself. The *Testis* gradually assumes its permanent form; the epididymis appears in the tenth week; and the gubernaculum (a membranous process from the filamentous tissue of the scrotum, analogous to the round ligament arising from the labium and attached to the ovary of the female), which is originally attached to the vas deferens, gradually fixes itself to the lower end of the testis or epididymis. The Testes begin to descend at about the middle period of pregnancy; at the seventh month they reach the inner ring; in the eighth they enter the passage, and in the ninth they usually descend into the scrotum. The cause of this descent is not very clear: it can scarcely be due merely, as some have supposed, to the contraction of the gubernaculum; since that does not contain any fibrous structure, until after the lowering of the testes has commenced. It is well known that the testes are not always found in the scrotum at the time of birth, even at the full period. Upon an examination of 97 new born infants, Wrisberg found both testes in the scrotum in 67, one or both in the canal in 17, in 8 one testis in the abdomen, and in 3 both testes within the cavity. Sometimes one or both testes remain in the abdomen during the whole of life; but this circumstance does not seem to impair their function.* This condition is natural, indeed, in the Ram. —The *Ovary* undergoes much less alteration, either in its intimate structure, or in its position. Its efferent canal (which, as just stated, is *not* the representative of the vas deferens of the male) remains detached from it, having a free terminal aperture, and thus constituting the Fallopian tube. The *Uterus* (which was formerly supposed to be formed by the coalescence of the Fallopian tubes), is now known to be derived, like the *Vagina*, from the genital portion of the 'uro-genital sinus' (§ 904), which is formed exactly on the same plan in both sexes alike, at an early period of fœtal development, and receives at its upper extremity the terminations of the Fallopian tubes. In the Female, this canal increases in size, and a marked separation is established between its lower or vaginal portion and its upper or uterine portion. The former opens into the undivided portion of the uro-genital sinus, which also receives the terminations of the urethra and of the Wolffian ducts, and which remains permanently unclosed. In the Male, on the other hand, the *sinus genitalis* makes no advance in development, and diminishes in relative size; so that at the period of fœtal maturity, it is only discoverable as the *vesicula prostatica*, which has been supposed until recently to be an appendage to the prostate gland. A transverse constriction in this canal marks-out its vaginal from its uterine portion; the former having exactly the same relation as in the female to the terminations of the urethra and of the Wolffian ducts (vasa deferentia) in the 'uro-genital sinus,' which is subsequently closed-in, however, so as apparently to form a continuation of the urethral canal; and the latter, in those Mammals whose females have a 'uterus bicornis,' exhibiting a like divarication into two lateral halves.†

* A case has lately occurred within the Author's knowledge, in which both testes remained in the abdomen until the tenth year, and then descended.

† See Prof. E. Weber's "Zusätze zur Lehre vom Baue und den Verrichtungen der Geschlechtsorgane," Leipzig, 1846; and Dr. Leuckart's Art. 'Vesicula Prostatica' in

904. The history of the development of the *external Organs of Generation* in the two sexes, presents matter of great interest, from the light which is thrown by a knowledge of it upon the malformations of these organs, which are among the most common of all departures from the normal type of Human organization.—Not only is the distinction of sexes altogether wanting at first; but the conformation of the external parts of the apparatus is originally the same in Man and the higher Mammalia, as it permanently is in the Oviparous Vertebrata. For, about the 5th or 6th week of embryonic life, the opening of a *cloaca* may be seen externally, which receives the termination of the intestinal canal, the ureters, and the efferent ducts of the sexual organs; but at the 10th or 11th week, the anal aperture is separated from that of the genito-urinary canal or 'uro-genital sinus,' by the development of a transverse band; and the uro-genital sinus itself is gradually separated by a like process of division, into a 'pars urinaria' and a 'pars genitalis,' the former of which, extending towards the urachus, is converted into the urinary bladder. A partial representation of this phase of development is found in the permanent condition of the Struthious Birds and of the Implacental Mammalia. The external opening of this canal is soon observed to be bounded by two folds of skin, the rudiments of the labia majora in the female, and of the two halves of the scrotum in the male, whilst between and in front of these, there is formed an erectile body, surmounted by a gland, and cleft or furrowed along its under surface. This body in the female is retracted into the genito-urinary canal, and becomes the clitoris, whilst the margins of its furrow are converted into the nymphæ or labia minora; and these bound the 'atrium vaginæ' or 'vestibule,' which receives the orifices of the urethra, of the vagina, and of Gaertner's canals when they are present, and which exactly represents, therefore, the 'sinus genitalis' of the early embryo. In the male, on the other hand, this sinus is nearly closed-in at a very early period, by the adhesion of the two folds of integument which bound it, forming that portion of the genito-urinary canal (improperly termed the 'urethra,') which receives the orifices of the vesical or true urethra, of the genital sinus (vesicula prostatica), and of the vasa deferentia; the erectile body increases in prominence, and becomes the penis, whilst the margins of the furrow at its under surface unite (at about the 14th week), to form the anterior continuation of the now-contracted genito-urinary canal, which is commonly termed the spongy portion of the urethra.

905. Now in a large proportion of cases of so-called *Hermaphrodism*, there has been either a want of completeness in the development of the Male organs, so that they present a greater or less degree of resemblance to those of the female; or the developmental process has gone-on to an abnormal extent in the Female organs, so that they come to present a certain degree of resemblance to those of the male.—One of the most common malformations of the *male* organ is 'hypospadias,' or an abnormal opening of the urethra at the base of the penis, arising from incompleteness in the closure of the edges of its original furrow. But when the

"Cyclop. of Anat. and Physiol.," vol. iv.—It was supposed by Prof. Weber, that the vesicula prostatica is the homologue of the uterus alone; but the Author considers it to have been satisfactorily established by the researches of Dr. Leuckart, that it answers to the uterus and vagina conjointly.

developmental process has been checked at an earlier period, the urogenital sinus may retain more nearly its original character, and may have a wide external opening beneath the root of the penis, so as to resemble the female vagina, whilst the penis is itself destitute of any trace of the urethral canal; in some of these cases, again, the testes have not descended into the scrotum; whilst the absence of beard, the shrillness of the voice, and the fulness of the mammæ, have contributed to impart a feminine character to these individuals, their male attributes, however, being determined by the *seminiferous* character of the essential organs, the testes.*—In the *female* organs, on the other hand, a greater or less degree of resemblance to those of the male may be produced by the enlargement of the clitoris, by its furrowing or complete perforation by the urethra, by the closure of the entrance of the vagina and the cohesion of the labia, so as to present a likeness to the unfissured perineum and scrotum of the male, by the descent of the ovaries through the inguinal ring into the position of the male testes, and by the imperfect development of the uterus and mammæ; with these abnormalities are usually associated roughness of the voice and growth of hair on the chin, and a psychical character more or less virile.—*True* Hermaphrodism, in which there is an absolute combination of the essential male and female organs in the same individual, is comparatively rare. It may occur under the forms of *lateral* hermaphrodism, in which there is a genuine ovary on one side and a testis on the other, in which case the external organs are usually those of a hypospadic male; *transverse* hermaphrodism, in which the external and internal organs do not correspond, the former being male and the latter female, or *vice versâ*,—and *double* or *vertical* hermaphrodism, in which the proper organs characteristic of one sex have existed, with the addition of some of those of the other; this is the rarest of all, and it is not certain that the coexistence of testes and ovaria on the same side has ever been observed in the Human species.†

906. We have now to follow the course of the development of the principal organs of *Animal* life; and shall first notice that of the *Skeleton*.—We have seen that, in the embryo of the Vertebrated animal, the future vertebral column is marked-out at an earlier period than any other permanent organ (§ 889), and that indications of a division into vertebræ are very speedily presented in the embryo of the higher classes. The earliest formation, however, is one of which we recognize no traces in the adult condition of Man; namely, a longitudinal column, tapering-off to a point at the cranial and caudal extremities of the embryo, and occupying the place of the future bodies of the vertebræ. This, which is termed the 'chorda dorsalis,' is of gelatinous consistence, and is composed entirely of cells; it is enclosed in a sheath, which gradually acquires the structure of a fibrous membrane, and which also invests the neural axis itself; and this condition is persistent in the Amphioxus and the Myxinoid Fishes, which have never any other spinal column than the chorda dorsalis. The vertebræ seem to be developed, in the inferior

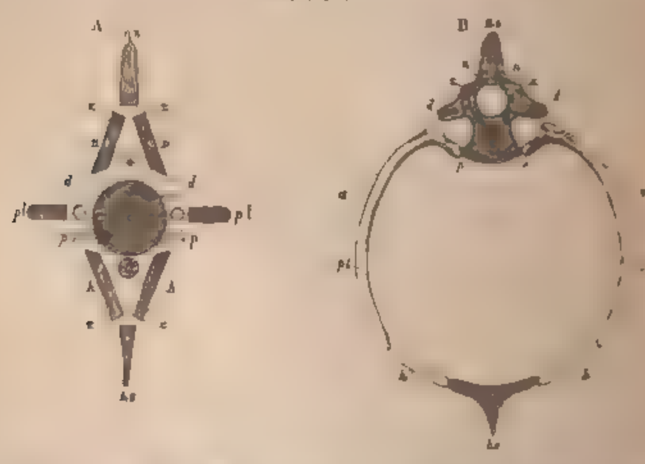
* The *vesicula prostatica* has presented an unusual development in some of these cases; see Prof. Weber (loc. cit.), and Prof. Theile's 'Account of a Case of Hypospadias,' in "Muller's Archiv.," 1847.

† On this subject, see Prof. Simpson's Article 'Hermaphrodism' in the "Cyclop. of Anat. and Phys.," vol. ii.

Vertebrata, in the fibrous sheath of the chorda dorsalis; but in Birds and Mammals, the quadrangular plates which show themselves at a very early period (Plate II., Fig. 12), appear to have an independent origin. These gradually increase in number and size, so as to surround the chorda both above and below; sending out, at the same time, prolongations from the inferior surface, to form the arches destined to enclose the Spinal Cord or neural axis, which are hence termed by Prof. Owen the *neural arches.* In this primitive condition, the body and arches of each vertebra are formed by one piece on each side; and these, becoming cartilaginous, are united inferiorly by a suture, so as to enclose the chorda in a sort of case formed by the bodies of the vertebræ, which are still hollow, allowing the segments of the chorda, partially separated from each other, to communicate together: this condition, also, remains persistent in certain of the Cartilaginous Fishes. With the concentric growth of the bodies of the vertebræ, however, the chorda dorsalis gradually wastes, and at last disappears; but previously to its disappearance, the ossification of the bodies and neural arches of the vertebræ begins, the former from a single point on the median line, the latter by separate points on the two sides.

907. The complete *typical vertebra* (Fig. 141, A) essentially consists, according to Prof. Owen,* of the *centrum*, around which are arranged

FIG. 141.



Elements of a *Vertebra* **according to Prof. Owen**:—A, ideal typical vertebra; B, actual thoracic vertebra of a Bird; c, centrum, giving-off d, d, the diapophyses, and p, p, the parapophyses; the neural arch, enclosing the spinal cord *, is formed by n, n, the neurapophyses and n s, the neural spine; the hæmal arch, enclosing the great centres of the circulation, is formed by h, h, the hæmapophyses, and h s, the hæmal spine. From both the neurapophyses and hæmapophyses may be given-off the zygapophyses z z. The lateral arches which may enclose the vertebral arteries o o, are completed by the pleurapophyses pl; these in B are bent downwards, so as to form part of the hæmal arch, and give-off the diverging appendages a, a.

four arches enclosed by processes in connection with it: viz., superiorly, the *neural* arch, which encloses the neural axis, and is formed by a pair

* See his "Archetype Skeleton," his "Lectures on Comparative Anatomy," vol. ii., and his "Discourse on the Nature of Limbs."

of 'neurapophyses' (*n, n*) and a 'neural spine' (*n s*), inferiorly the *hæmal* arch, which is in like special relation with the centres of the circulation, but may be expanded around the Visceral cavity generally, and which is formed of a pair of 'hæmapophyses' (*h, h*) and the 'hæmal spine' (*h s*), and two *lateral* arches, enclosing vascular canals, which are bounded by the 'diapophyses' (*d, d*) and the 'parapophyses' (*p, p*), and are completed by the 'pleurapophyses' (*pl, pl*). Of these elements, the centrum is the most constant, and next to these are the neural arches, which we find in every part of the vertebral column through which the neural axis passes, and which are enormously developed in the cranial segments, in accordance with the high development of their nervous mass. The hæmal arches are often almost entirely deficient, as in the cervical and lumbar vertebræ of Man and the Mammalia; but in the dorsal vertebræ they are very largely developed, and the elements of the lateral arches are brought into connection with them, so as to form the enclosure of the visceral cavity (Fig. 141, B). From the pleurapophyses are occasionally developed a pair of 'diverging appendages' (*a, a*), which are well seen in the ribs of Birds; and these are considered by Prof. Owen to be the fundamental elements of the bones of the 'extremities' or 'limbs,' those of the anterior extremity being the diverging appendages of the occipital vertebra (§ 908), and those of the posterior extremity standing in the same relation to one of the sacral vertebræ.*—The extremities make their first appearance, in all Vertebrata, as leaf-like elevations from the parietes of the trunk (Fig. 137, *q q, r r*); those peculiarities of form by which they are adapted to specialities of function, being determined by subsequent processes of development. Thus in the Human fœtus, the fingers are at first united by the primitive blastema, as if webbed for swimming; but this, as Prof. Muller justly remarks, is less to be regarded as an approximation to the form of the extremity characteristic of aquatic animals, than as the primitive and most general form of the hand, the individual parts of which subsequently become more completely isolated in such animals as require to use them separately.

908. It is in the *cranial* segments, that the Vertebral elements undergo their most remarkable transformations, the departure from the 'archetype' being more complete in Man than in any other animal; so that it is only by tracing them through their simplest to their most complicated forms and arrangements, that the true nature of the latter can be elucidated.—The number of the segments entering into the skull has been a subject of much discussion among those who adopt the 'vertebral theory' of its composition; but Prof. Owen agrees with Oken (the original propounder of that theory) in fixing the number at *four*, which corresponds with that of the primary divisions, succeeding each other in a linear series, that are distinctly marked-out in the early development of the Encephalon, namely (proceeding from behind forwards), the Epencephalon, the Mesencephalon, the Prosencephalon, and the Rhinencephalon (§ 909), and also corresponding with the number of the nerves of special sense, the Auditory, Gustative, Optic, and Olfactory,

* The beautiful chain of reasoning by which this position is, in the Author's opinion, irrefutably established, is contained in the works of Prof. Owen already referred to; a sketch of it, and of the whole 'Vertebral Theory,' will be found in the Author's "Principles of General Physiology."

which issue from this part of the neural axis with the same segmental regularity that the ordinary sensori-motor nerves do elsewhere. Under the guidance of the unerring light of Comparative Anatomy and Development, the composition of the *Cranial* portion of the skull—consisting of the *bodies* and *neural arches* of the four cranial vertebræ—has been determined by Prof. Owen as follows, each of the 'elements' enumerated being marked as distinct, by the separateness of its Centre of Ossification.

TABLE I.

Composition of the Neural Arches of the Cranial Vertebræ, in Man.

I. Epencephalic or Occipital Vertebra.

Centrum; Basi-occipital portion of the Occipital bone.
Parapophyses; *Neurapophyses*; Coalesced into the lateral or condyloid portions of the Occipital bone, the parapophyses being marked by the scabrous ridge giving attachment to the rectus lateralis muscle.
Neural Spine; Proper Occipital bone.

II. Mesencephalic or Parietal Vertebra.

Centrum; Basi-sphenoid, or body of the posterior or spheno-temporal part of the Sphenoid bone.
Parapophyses; Mastoid portion of the Temporal bones.
Neurapophyses; Great wings of Sphenoid bone, or Ali-sphenoids.
Neural Spine; Parietal bones.

III. Prosencephalic or Frontal Vertebra.

Centrum; Pre-sphenoid, or body of the anterior or spheno-orbital part of the Sphenoid bone.
Parapophyses; External angular processes of Frontal bone (the post-frontals of Fishes).
Neurapophyses; Small wings of Sphenoid bone, or Orbito-sphenoids.
Neural Spine; Frontal bone.

IV. Rhinencephalic or Nasal Vertebra.

Centrum; Vomer.
Neurapophyses; Ossa plana of Ethmoid bone.
Neural Spine; Nasal bones.

[In connection with the foregoing, we have two ossified 'sense-capsules,' the Auditory forming the petrosal portion of the Temporal bone, and the Nasal forming the principal part of the Ethmoid bone with the Turbinate bones.]

The mode in which the bones of the *Face* and of some other parts are formed from the *hæmal* or *visceral arches* of the cranial vertebræ, will be seen from the following table.

TABLE II.

Composition of the Hæmal Arches of the Cranial Vertebræ, in Man.

I. Epencephalic or Occipital Vertebra.

Pleurapophyses; Scapulæ.
Diverging Appendages; Bones of Arm, Fore-arm, and Hand.
Hæmapophyses; Coracoid processes of Scapulæ (Coracoid bones of Oviparous Vertebrata).
Hæmal Spine; Deficient.

[The Clavicles and first segment of the Sternum, which complete the Scapular arch in the Mammalia, are regarded by Prof. Owen as the hæmapophyses and hæmal spine of the Atlas, or highest vertebra of the trunk.]

II. Mesencephalic or Parietal Vertebra.

Pleurapophyses, Styloid processes of Temporal bone.
Diverging Appendages, Greater cornua of Hyoid bone, or Thyro-hyals.
Hæmapophyses, Lesser cornua of Hyoid bone, or Cerato-hyals.
Hæmal Spine, Body of Hyoid bone.

III. Prosencephalic or Frontal Vertebra.

Pleurapophyses, Tympanic portion of Temporal bone.
Diverging Appendages, Deficient.
Hæmapophyses, Articular portion of Inferior Maxilla.
Hæmal Spine, Dental portion of Inferior Maxilla.

IV. Rhinencephalic or Nasal Vertebra.

Pleurapophyses; Palatine bones.
Diverging Appendages; Pterygoid and Malar bones, with squamosal and zygomatic portions of Temporal bones.
Hæmapophyses, Superior Maxillary bones.
Hæmal Spine, Intermaxillary bones.

Thus we see that, in the anterior segment, we have the highest development of the Visceral portion, co-existing with the lowest development of the Neural, this last being obviously related to the comparatively low development of the ganglionic mass which it is destined to protect.—The development of the soft parts of the face takes place in conformity with that of the vertebral segments; these being formed by 'visceral arches' which meet on the median line (Fig. 137, *c*, *d d*); and the knowledge of this fact enables us to explain those congenital malformations which result from want of union of the two halves on the median plane, such as cleft-palate and hare-lip.

909. Within the Cranio-spinal canal thus formed, the rudiment of the Cerebro-spinal axis is found, at first under a very different aspect from that which it subsequently presents, especially as regards the relative proportion of its different segments. The Encephalon, at about the 6th week, is seen as a series of vesicles arranged in a line with each other (Fig. 142), of which those that represent the Cerebrum (*b*) are the smallest, whilst that which represents the Cerebellum (*d*) is the largest. The latter (or *Epencephalon*), as in Fishes, is single, covering the fourth ventricle on the dorsal surface of the Medulla Oblongata. Anterior to this is the single vesicle (*a*) of the Corpora Quadrigemina (or *Mesencephalon*), from which the optic nerves partly arise, this has in its interior a cavity, the ventricle of Sylvius, which is persistent in the adult Bird, though obliterated in the adult Mammal. In front of this is the vesicle (*c*) of the Third Ventricle (or *Deutencephalon*), which also contains the Thalami Optici; as development proceeds, this, like the preceding, is covered by the enlarged Hemispheres; whilst its roof becomes cleft

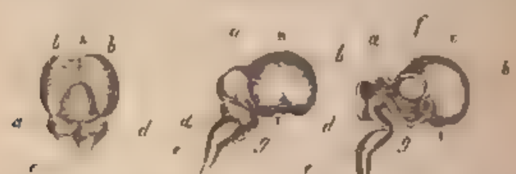
Fig. 142.

Human Embryo of sixth week, enlarged about three times: *a*, vesicle of Corpora Quadrigemina; *b*, vesicle of Cerebral Hemispheres; *c*, vesicle of Third Ventricle; *d*, vesicle for Cerebellum and Medulla Oblongata; *e*, auditory vesicle; *f*, olfactory fossa; *h*, liver; * * caudal extremity.

anteriorly on the median line, so as to communicate with the cavities which they include. Still more anteriorly (*b*) is the double vesicle (or *Prosencephalon*) which represents the hemispheres of the Cerebrum; this has a cavity on either side, the floor of which is formed by the Corpora Striata, and which has at first no opening except into the third ventricle; the 'fissure of Sylvius' (which enables the membranes of the brain to be reflected into the lateral ventricles) being formed at a later period. The *Rhinencephalon* (consisting of the Olfactive ganglia) is seldom distinctly marked-out in the early stage of development of the higher Vertebrata, though very obvious in that of Fishes.—Thus in the small proportion which the Cerebral Hemispheres bear to the other parts, in the absence of convolutions, in the deficiency of commissures, and in the general simplicity of structure of the whole, there is a certain correspondence between the brain of the Human embryo at this period, and that of a Fish; but the resemblance is much stronger between the *fœtal* brain of the Fish and that of the Mammal; indeed at this early period of their formation, the two could scarcely be distinguished; and it is the large amount of change which the latter undergoes, as compared with the former, that causes the wide dissimilarity of their adult forms.

910. At about the 12th week, we find the Cerebral Hemispheres much increased in size, and arching-back over the Thalami and Corpora Quadrigemina (Fig. 143); still, however, they are destitute of convolu-

FIG. 143.



Brain of *Human Embryo* at twelfth week. A, seen from behind; B, side view; C, sectional view; *a*, corpora quadrigemina; *bb*, hemispheres; *d*, cerebellum; *e*, medulla oblongata; *f*, optic thalamus; *g*, floor of third ventricle; I, olfactory nerve.

tions, and are imperfectly connected by commissures; and there is a large cavity yet existing in the Corpora Quadrigemina, which freely communicates with the Third Ventricle. In all these particulars, there is a strong analogy between the condition of the brain of the Human embryo at this period, and that of the Bird.—Up to the end of the 3rd month, the Cerebral Hemispheres present only the rudiments of *anterior* lobes, and do not pass beyond that grade of development which is permanently characteristic of the Marsupial Mammalia, the Thalami being still but incompletely covered-in by them. During the 4th and part of the 5th months, however, the middle lobes are developed from their posterior aspect, and cover the Corpora Quadrigemina; and the posterior lobes, of which there was no previous rudiment, subsequently begin to sprout from the back of the middle lobes, remaining separated from them, however, by a distinct furrow, even in the brain of the mature fœtus and sometimes in that of older persons. In these and other particulars, there is a very close correspondence between the progressive stages of

development of the Human Cerebrum, and those which we encounter in the ascending series of Mammalia.*

911. The development of the two principal Organs of Sense, the Eye and the Ear, has been made the subject of careful study (in the Chick) by Mr H. Gray.†—The development of the *Eye* commences by a protrusion from the posterior part of the anterior cerebral vesicle, representing the 'vesicle of the thalami optici,' which is at that time hollow; and the cavity of the protrusion is continuous with that of the vesicle itself, which remains as the 'third ventricle.' This protrusion is lined, like the cerebral vesicle, with granular matter, which gradually becomes distinctly cellular, forming a layer of a truly ganglionic character; and whilst this change is taking place, the protrusion increases, becomes pear-shaped, and is at last connected only by a narrow pedicle with the vesicle from which it sprang. This pedicle closes-up, so as completely to separate the two cavities; and the one which has been thus budded forth constitutes the rudiment of the eye, whilst the other goes-on to form the ganglionic bodies at the base of the cerebrum, the connecting pedicle becoming the optic nerve, which connects the retina with its ganglionic centre. The spherical extremity of the protrusion is absorbed, and the retina, or vesicular lining, becomes attached to the margin of the lens, which is in the mean time developed in the interior of the cavity, and is at first completely surrounded by the retina. The formation of the Coats of the eye takes-place subsequently, the development even of the 'fibrous lamina' and of the 'membrana Jacobi' of the Retina itself, not proceeding until after its cellular layer has been very distinctly formed. It is a curious circumstance, and one not very easy to account for, that the development of the Eye should commence from the Deutencephalic and not from the Mesencephalic vesicle; as it is in the latter that the proper 'optic ganglia' originate, with which the optic nerves come at last to have their principal connection, their connection with the 'thalami optici' being much less close.—The *Auditory* apparatus takes its origin in a portion of the Epencephalic vesicle, which protrudes on either side; its cavity at first communicating with that of the vesicle, which remains permanent as the 'fourth ventricle.' As its protrusion increases, it becomes elongated and pear-shaped, and is only connected with the central mass by a pedicle whose canal gradually closes-up; the sac thus cut-off becomes the vestibular cavity, and the pedicle the auditory nerve. At first there is no vestige either of cochlea, semicircular canals, or tympanic apparatus; but the sac presents the simple character which it permanently retains in the Cephalopoda and the lower Fishes. Gradually, however, the semicircular canals are developed, by a contraction and folding-in of the walls of the vestibular sac; and the cochlea is probably formed as an offset from it. At the same time, the formation of cartilage, and subsequently of bone, takes place around the auditory sac and its prolongations, forming the 'sense-capsule,' which, in the higher Vertebrata, coalesces with the vertebral elements to form the temporal bone. It is very interesting to remark, that the *membranous labyrinth*, between the eighth and thirteenth

* See an account of the observations of Prof. Retzius on the Development of the Cerebrum, in the "Archives d'Anatomie Générale et de Physiologie," 1846.

† "Philosophical Transactions," 1850.

days in the Chick, has a structure almost precisely similar to that of the *retinal expansion* of the same period; consisting, like it, of a distinct but very delicate fibrous mesh, in the spaces between which are deposited a quantity of granular matter and numerous nucleated cells, whilst its exterior is composed of a dense mass of nuclei, almost precisely analogous to the granular particles which form a large part of the entire substance of the retina.

912. *Of Sex.*—Although nothing is known of the conditions on which the differentiation of Sex immediately depends, yet there is strong statistical evidence that the relative numbers of Males and Females are in some way influenced by the relative *ages* of the parents. The following table expresses the average results collected by M. Hofacker* in Germany, and by Mr. Sadler† in Britain; between which it will be seen that there is a very striking general correspondence, although both were drawn from a too-limited series of observations. The numbers indicate the proportion of Male births to 100 Females, under the several conditions mentioned in the first column:—

	Hofacker		Sadler
Father younger than Mother . .	90·6	Father younger than Mother	86·5
Father and Mother of equal age .	93·0	Father and Mother of equal age	94·8
Father older by 1 to 6 years . .	103·4	Father older by 1 to 6 years . .	103·7
„ „ 6 to 9 .	124·7	„ „ 6 to 11 . . .	126·7
„ „ 9 to 18	143·7	„ „ 11 to 16 . . .	147·7
„ „ 18 and more .	200·0	„ „ 16 and more .	163·2

From this it appears, that the more advanced age of the Male parent has a very decided influence in occasioning a preponderance in the number of Male infants, and this tallies with the fact, that taking the average of the whole of Europe, over which (as a general rule) the state and customs of society bring-about a decided preponderance of age, among married couples, on the side of the husband, the proportion is about 106 males to 100 females. This does not hold good, however, in regard to *illegitimate* offspring, the parents of which may generally be presumed to be more nearly on an equality in this respect, and it is curious that the proportion of these has averaged 102·5 males to 100 females, in places where the proportion of *legitimate* births was 105¾ males to 100 females.—We are not likely to obtain data equally satisfactory in regard to the influence of more advanced age on the part of the Female parent; as a difference of 10 or 15 years on that side is not so common. If it exist to the same extent, it is probable that the same law would be found to prevail in regard to Female children born under such circumstances, as will be stated (§ 913) with respect to the Male,—namely, that the mortality is greater during embryonic life and early infancy, so that the preponderance is reduced. Even at birth, there is a manifest difference in the physical conditions of infants of different sexes; for, in the average of a large number, there is a decided preponderance on the side of the Males, both as to the length and the weight of the body. And it seems not improbable that this difference has a decided influence upon the greater loss of life in the act of parturition, which occurs among Male infants.

* "Annales d'Hygiène," Oct. 1829. † "Law of Population," vol. ii. p. 343

i. The *Length* of the body in fifty new-born infants of each sex, as ascertained by Quetelet,* was as follows.—

	Males.	Females.	Total.
From 16 to 17 inches† (French)	2	4	6
,, 17 to 18	8	19	27
,, 18 to 19	28	18	46
,, 19 to 20	12	8	20
,, 20 to 21	0	1	1

From these observations, the mean and the extremes of the Lengths of the *male* and *female* respectively, were calculated to be,—

	Males.		Females.	
Minimum	16 inches,	2 lines	16 inches,	2 lines.
Mean	18	6	18	1½
Maximum	19	8	20	6

Notwithstanding that the *maximum* is here on the side of the Female (this being an accidental result, which would probably have been otherwise, had a larger number been examined), the *average* shows a difference of 4½ lines in favour of the Male.

ii. The inequality in the *Weights* of the two is even more remarkable; the observations of M. Quetelet‡ were made upon 63 male and 56 female infants.

Infants weighing from	Males.	Females.	Total.
1 to 1½ kilog.§	0	1	1
1½ to 2	0	1	1
2 to 2½	3	7	10
2½ to 3	13	14	27
3 to 3½	28	23	51
3½ to 4	14	7	21
4 to 4½	5	3	8

The extremes and means were as follows:—

	Males.	Females.
Minimum	2·34 kilog.	1·12
Mean	3·20	2·91
Maximum	4·50	4·25

iii. The average Weight of infants of both sexes, as determined by these inquiries, is 3·05 kilog. or 6·77 lbs.; and this corresponds almost exactly with the statement of Chaussier, whose observations were made upon more than 20,000 infants. The mean obtained by him, without reference to distinction of sex, was 6·75 lbs.; the maximum being 11·3 lbs., and the minimum 3·2 lbs.‖ The average in this country is probably rather higher; according to Dr. Joseph Clarke,¶ whose inquiries were made on 60 males and 60 females, the average of Male children is 7½ lbs.: and that of Females 6⅞ lbs. He adds that children which at the full time weigh less than 5 lbs. rarely thrive; being generally feeble in their actions, and dying within a short time. Several

* "Sur l'Homme," tom. ii. p. 8.
† The French inch is about one fifteenth more than the English.
‡ Op. cit. tom. ii. p. 35.
§ The kilogramme is equal to 2·22 lbs. avoirdupois.
‖ These numbers have been erroneously stated in many Physiological works; owing to the difference between the French and English pound not having been allowed-for.
¶ "Philosophical Transactions," vol. lxxvi.

instances are on record, of infants whose weight at birth exceeded 15lbs. It appears that healthy females, living in the country, and engaged in active but not over-fatiguing occupations, have generally the largest children; and this is what might be expected *à priori*, from the superior energy of their nutritive functions.

913. There appears to be, from the first, a difference in the *Viability* (or probability of life) of Male and Female children; for, out of the total number born dead, there are 3 Males to 2 Females: this proportion gradually lessens, however, during early infancy; being about 4 to 3 during the first two months, and about 4 to 5 during the next three months, after which time the deaths are nearly in proportion to the numbers of the two sexes respectively, until the age of puberty. The viability of the two sexes continues to increase during childhood, and attains its maximum between the 13th and 14th years. For a short time after this epoch has been passed, the rate of mortality is higher in Females than in Males; but from about the age of 18 to 28, the mortality is much greater in Males, being at its maximum at 25, when the viability is only half what it is at puberty. The fact is a very striking one; and shows most forcibly that the indulgence of the passions not only weakens the health, but in a great number of instances is the cause of a very premature death. From the age of 28 to that of 50, the mortality is greater and the viability less on the side of the Female, this is what would be anticipated from the increased risk to which she

Fig. 144.

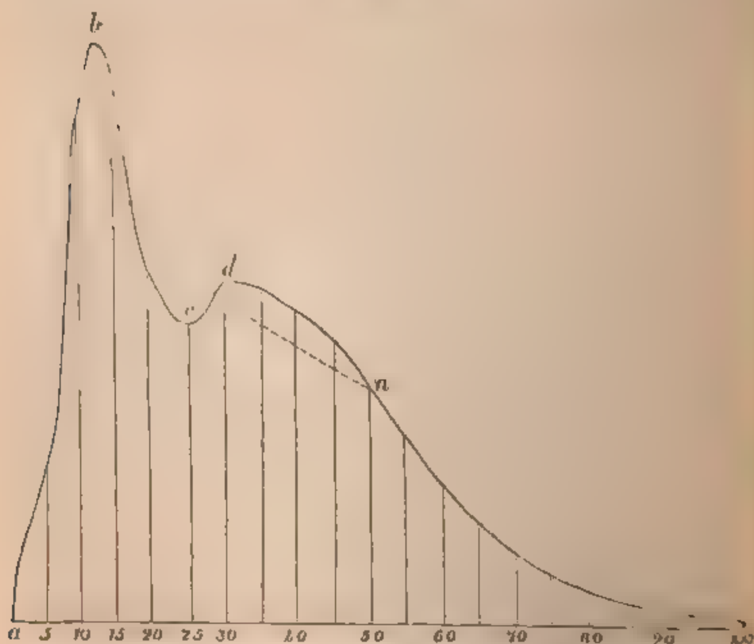


Diagram representing the *Comparative Viability of the Male and Female* at different Ages.

is liable during the parturient period. After the age of 50, the mortality is nearly the same for both.—These facts have been expressed by Quetelet (Op. cit.) in a form which brings them prominently before the eye (Fig. 144). The relative viability of the Male at different ages is represented by a curved line; the elevation of which indicates its degree, at the respective periods marked along the base line. The dotted line which follows a different curve, represents the viability of the Female. Starting from *a*, the period of birth, we arrive at the maximum of viability for both at *b*: from this point, the Female curve steadily descends towards *n*, at first very rapidly, but afterwards more gradually; whilst the male curve does not quite descend so soon, but afterwards falls much lower, its minimum being *c*, which corresponds with the age of 25 years. It afterwards ascends to *d*, which is the maximum of viability subsequently to the age of puberty; this point is attained at the age of 30 years, from which period, up to 50, the probability of life is greater in the Male than in the Female. In the decline of life, there seems little or no difference for the two sexes.

914. Similar diagrams have been constructed by Quetelet, to indicate the relative Heights and Weights of the two sexes at different ages (Fig. 145).—In regard to *Height* it may be observed, that the increase is most rapid in the first year, and that it afterwards diminishes gradually; between the ages of 5 and 16 years, the annual increase is very regular. The difference between the Height of the Male and Female, which has been already stated to present itself at birth, continues to increase during infancy and youth; it is not very decided, however, until about the 15th year, after which the growth of the Female proceeds at a much-diminished rate, whilst that of the Male continues in nearly the same degree, until about the age of 19 years. It appears, then, that the

FIG. 145.

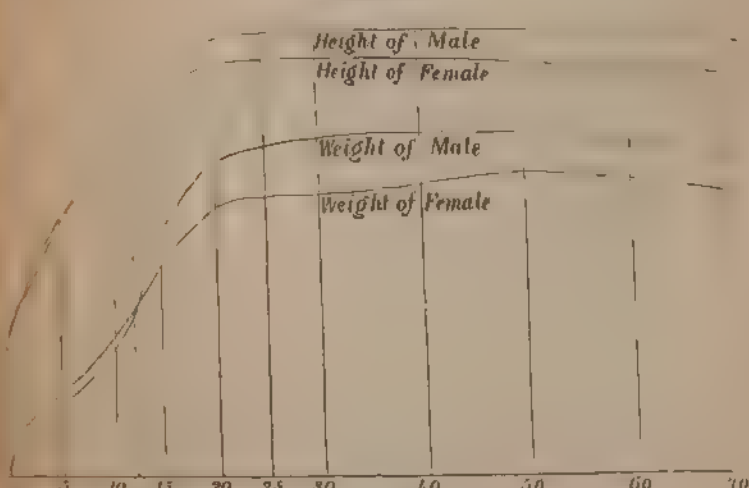


Diagram representing the *Comparative Heights and Weights* of the Male and Female at different Ages.

Female comes to her full development in regard to Height, earlier than does the Male. It seems probable, from the observations of Quetelet, that the full Height of the Male is not generally attained until the age of 25 years. At about the age of 50, both Male and Female undergo a diminution of their stature, which continues during the latter part of life.—The proportional *Weight* of the two sexes at different periods, corresponds pretty closely with their height. Starting from birth, the predominance then exhibited by the Male gradually increases during the first few years, but towards the period of puberty, the proportional weight of the Female increases; and at the age of 12 years, there is no difference between the two sexes in this respect. The weight of the Male, however, then increases much more rapidly than that of the Female, especially between the ages of 15 and 20 years; after the latter period, there is no considerable increase on the side of the Male, though his maximum is not attained until the age of 40; and there is an absolute diminution on the part of the Female, whose weight remains less during nearly the whole period of child bearing. After the termination of the parturient period, the weight of the Female again undergoes an increase, and its maximum is attained at about 50. In old age, the weight of both sexes undergoes a diminution in nearly the same degree. The average Weights of the Male and Female that have attained their full development, are 20 times those of the new-born Infants of the two sexes respectively. The Heights, on the other hand, are about 3¼ times as great.

915. The chief differences in the *Constitution* of the two sexes manifest themselves during the period when the Generative function of each is in its greatest vigour. Many of these distinctions have been already alluded to; but there are others of too great importance to be overlooked; and these chiefly relate to the Nervous System and its functions. There is no obvious structural difference in the Nervous System of the two sexes (putting aside the local peculiarities of its distribution to the organs of generation), save the inferior size of the Cerebral Hemispheres in the Female. This difference, which is not observed in other parts of the Encephalon, is readily accounted-for on the principles formerly stated (§ 574), when we compare the psychical character of Woman with that of Man; for there can be no doubt that —putting aside the exceptional cases which now and then occur—the *intellectual* powers of Woman are inferior to those of Man. Her *intuitive* powers are certainly greater than his; her perceptions are more acute, her apprehensions quicker; and she has a remarkable power of interpreting the feelings of others, which gives to her, not only a much more ready sympathy with them, but that facility in guiding her actions so as to be in accordance with them, which we call *tact*. This tact bears a close correspondence with the *unconscious adaptiveness* to particular ends, which we see in Instinctive actions. Notwithstanding the superiority of her perceptive faculties, her capability of sustained mental exertion is much less; and though her views are often peculiarly distinguished by the clearness and decision which result from the strength of her intuitive sense, they are generally deficient in that comprehensiveness which brings the *whole* case to be judged-of, and which is consequently necessary for their stability. With less of *volitional* power

than Man possesses, she has the *emotional* in a much stronger degree. The emotions, therefore predominate, and more frequently become the leading springs of action, than they are in Man. By their direct influence upon the bodily frame, they produce changes in the Organic functions, which far surpass in degree anything of the same kind that we ordinarily witness in Man; and they thus not unfrequently occasion symptoms of an anomalous kind, which are very perplexing to the Medical practitioner, though very interesting to the Physiological observer. But they also act as powerful motives to the Will, and, when strongly called-forth, produce a degree of vigour and determination, which is very surprising to those who have usually seen the individual under a different aspect. But this vigour, being due to the strong excitement of the Feelings, and not to any inherent strength of Intellect, is only sustained during the persistence of the motive, and fails as soon as this subsides. The feelings of Woman, being frequently called-forth by the occurrences she witnesses around her, are naturally more disinterested than those of Man; *his* energy is more concentrated upon one object, and to this his Intellect is directed with an earnestness that too frequently either blunts his feelings, or carries them along in the same channel, thus rendering them selfish.—In regard to the inferior development of her Intellectual powers, therefore, and to the predominance of the Instinctive, Woman must be considered as ranking below Man; but in the superior purity and elevation of her Feelings, she is as highly raised above him. Her whole character, Psychical as well as Corporeal, is beautifully adapted to supply what is deficient in Man; and to elevate and refine those powers, which might otherwise be directed to low and selfish objects.

5. —*Of Lactation.*

916. The new-born Infant in the Human species, as in the class of Mammalia generally, is supplied with nourishment by a secretion elaborated from the blood of its maternal parent, by certain glandular organs known as the *Mammary*. The structure of these, which has been thoroughly investigated by Sir A. Cooper* and Mr. Birkett,† is extremely simple. Each gland is composed of a number of separate glandules, which are connected together by fibrous or fascial tissue, in such a manner as to allow a certain degree of mobility of its parts, one upon another, which may accommodate them to the actions of the Pectoralis muscle whereon they are bound down; and the glandules are also connected by the ramifications of the lactiferous tubes, which intermingle with one another in such a manner as to destroy the simplicity and uniformity of their divisions, although they rarely inosculate. The *mammillary tubes*, or terminal ducts contained in the nipple, are usually about ten or twelve in number; they are straight, but of somewhat variable size; and their orifices, which are situated in the centre of the nipple, and are usually concealed by the overlapping of its sides, are narrower than the tubes themselves. At the base of the nipple, these tubes dilate into reservoirs, which extend beneath the areola and to some distance into the gland,

* "On the Anatomy of the Breast," 1840.
† "The Diseases of the Breast, and their Treatment," 1850.

when the breast is in a state of lactation. These are much larger in many of the lower Mammalia, than they are in the Human female; their use is to supply the immediate wants of the child when it is first applied to the breast, so that it shall not be disappointed, but shall be induced to proceed with sucking until the 'draught' be occasioned (§ 833). From each of these reservoirs commence five or six branches of the *lactiferous tubes*, each of which speedily subdivides into smaller ones; and these again divaricate, until their size is very much reduced, and their extent greatly increased (Fig. 146). These, like the reservoirs and mammillary

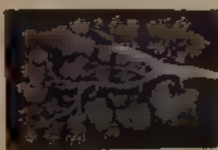
Fig. 146.

Distribution of the *Milk-ducts* in the Mamma of the Human female, during lactation; the ducts injected with wax.

tubes, are composed of a fibrous coat lined by a mucous membrane; the latter is highly vascular, and forms a secretion of its own, which sometimes collects in considerable quantity when the milk ceases to be produced. The smaller subdivisions of the lactiferous tubes proceed to distinct lobuli in each glandule; so that when a branch of a mammillary tube has been filled with injection, its attached lobules, if separated from each other by long maceration, are like a bunch of fruits clustered upon a stalk (Fig. 147). When the lactiferous tubes are pursued to their ultimate distribution, they are found to terminate in follicles, whose size in full lactation, is that of a hole pricked in paper by the point of a very

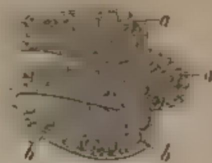
fine pin, so that, when distended with quicksilver or milk, they are just visible to the naked eye; at other times, however, the follicles do not admit of being injected, though the lactiferous tubes may have been completely filled. They are lined by a continuation of the same membrane

Fig. 147.



Termination of portion of *Milk duct in a cluster of follicles*, from a mercurial injection, enlarged four times.

Fig. 148.



Ultimate follicles of Mammary gland, with their secreting cells a, a, and nuclei, b, b.

with that which lines the ducts; and this possesses a high vascularity. The arteries which supply the glandules with blood, become very large during lactation; and their divisions spread themselves minutely on the follicles. From the blood which they convey, the milk is secreted and poured into the follicles, whence it flows into the ducts. The inner surface of the milk-follicles, in common with other glandular structures, is covered with a layer of epithelium-cells (Fig. 148), as was first observed by Prof. Goodsir; and these, being seen to contain milk-globules, may without doubt be regarded as the real agents in the secreting process. Absorbent vessels are seen to arise in large numbers in the neighbourhood of the follicles; their function appears to be, to absorb the more watery part of the milk contained in the follicles and tubes, so as to render it more nutrient than it is when first secreted, and also to relieve the distension which would occur, during the absence of the child, from the continuance of the secreting process.

917. The Mammary gland may be detected at an early period of fœtal existence, being easily distinguishable from the surrounding parts by the redness of its colour and its high vascularity, especially when the whole is injected. At this period, it presents no difference in the male and female; and it is not until near the period of puberty that any striking change manifests itself, the gland continuing to grow, in the one sex as in the other, in proportion to the body at large. At about the age of thirteen years, however, the enlargement of the gland commences in the Female: and by sixteen, it is greatly evolved, and some of the lactiferous tubes can be injected. At about the age of twenty, the gland attains its full size previous to lactation; but the milk-follicles cannot even then be injected from the tubes. During pregnancy, the mammæ receive a greatly-increased quantity of blood. This determination often commences very early, and produces a feeling of tenderness and distension, which is a valuable sign (where it exists in connection with others) of the commencement of gestation (§ 870). A true lacteal secretion usually commences about the third or fourth month of pregnancy, and may be obtained by pressure carefully applied. This may be turned to useful account, in diagnosing cases of concealed or doubtful pregnancy from cases of simple

suppression of the catamenia; but it will not serve to distinguish true pregnancy from spurious, or from the distension of the uterus by tumours.* The vascularity of the gland continues to increase during pregnancy; and at the time of parturition, its lobulated character can be distinctly felt. The follicles are not, however, developed sufficiently for injection, until lactation has commenced. After the cessation of the catamenia from age, so that pregnancy is no longer possible, the lactiferous ducts continue open, but the milk-follicles are incapable of receiving injection. The substance of the glandules gradually disappears, so that in old age only portions of the ducts remain, which are usually loaded with mucus; but the place of the glandules is commonly filled up by adipose tissue, so that the form of the breast is preserved. Sir A. Cooper notices a curious change, which he states to be almost invariable with age; namely, the ossification of the arteries of the breast, the large trunks as well as the branches, so that their calibre is greatly diminished or even obliterated.

918. The Mammary gland of the Male is a sort of miniature picture of that of the Female. It varies extremely in its magnitude; being in some persons of the size of a large pea; whilst in others it is an inch, or even two inches, in diameter. In its structure it corresponds exactly with that of the female, but is altogether formed on a smaller scale. It is composed of lobules containing follicles, from which ducts arise; and these follicles and ducts are not too minute to be injected, although with difficulty. The evolution of the gland goes-on *pari passu* with that of the body, not undergoing an increase at any particular period; it is sometimes of considerable size in old age. A fluid, which is probably mucus, may be pressed from the nipple in many persons; and this in the dead body, with even more facility than in the living. That the essential character of the gland is the same in the male as in the female, is shown by the instances, of which there are now several on record, in which infants have been suckled by men (§ 919).

919. Although the state of functional activity in the Mammary gland is usually limited to the epoch succeeding Parturition, yet this is not invariably the case; for numerous instances are on record, in which young women who have never borne children, and even old women long past the period of child bearing, have had such a copious flow of milk, as to be able to act as efficient nurses.† In these cases, the strong desire to furnish milk, and continued irritation of the nipple by the infant's mouth, seem to have furnished the stimulus requisite for the formation of the secretion; and it has been found that this is usually adequate to *restore* the secretion, after it has been intermitted for some months during the ordinary period of lactation, in consequence of disorder or debility on the part of the mother, or any other cause; so that where her condition renders it advisable that she should discontinue nursing for a time the child may be withdrawn and the milk 'dried-up,' with a confident expectation that the secretion may be reproduced subsequently.‡ Dr

* See the valuable paper by Dr. Peddie, 'On the Mammary Secretion,' in the "Edinb. Monthly Journ.," Aug. 1848.

† A collection of such cases is given in Dr. Dunglison's "Human Physiology," 7th edit., vol. ii. p. 513.

‡ See an account of M. Trousseau's experience on this point, in "L'Union Méd-

M'William mentions in his Report of the Niger Expedition,* that the inhabitants of Bona Vista (Cape de Verde Islands) are accustomed to provide a wet nurse in cases of emergency, in the person of any woman who has once borne a child and is still within the age of child-bearing, by continued fomentation of the mammæ with a decoction of the leaves of the *jatropha curcas*, and by suction of the nipple.—The most curious fact, however, is that even *Men* should occasionally be able to perform the duties of nurses, and should afford an adequate supply of infantile nutriment. Several cases of this kind are upon record;† but one of the most recent and authentic is that given by Dr. Dunglison.‡ "Professor Hall, of the university of Maryland, exhibited to his Obstetrical class, in the year 1837, a coloured man, fifty-five years of age, who had large, soft, well-formed mammæ, rather more conical than those of the female, and projecting fully seven inches from the chest, with perfect and large nipples. The glandular structure seemed to the touch to be exactly like that of the female. This man had officiated as wet nurse, for several years, in the family of his mistress, and he represented that the secretion of milk was induced by applying the children entrusted to his care, to the breasts, during the night. When the milk was no longer required, great difficulty was experienced in arresting the secretion. His genital organs were fully developed." Corresponding facts are also recorded of the male of several of the lower animals.

920. The secretion of *Milk* consists of Water holding in solution Sugar, various Saline ingredients, and the peculiar albuminous substance termed Casein, and having Oleaginous particles suspended in it. The constitution of this fluid is made evident by the ordinary processes to which it is subjected in domestic economy. If it be allowed to stand for some time, exposed to the air, the greater part of the oleaginous globules come to the surface, being of less specific gravity than the fluid through which they are diffused: this is especially the case with the larger facetted globules, which have been hence distinguished as 'cream globules.' The *cream* thus formed does not, however, consist of oily particles alone; but includes a considerable amount of casein, with the sugar and salts of the milk. These are further separated by the continued agitation of the cream; which, by rupturing the envelopes of the oil-globules, separates it into *butter*, formed by their aggregation, and *buttermilk*, containing the casein, sugar, &c. A considerable quantity of casein, however, is entangled with the oleaginous matter, and this has a tendency to decompose, so as to render the butter rancid, it may be separated by keeping

ale," 1852, No. 7; and paper by Dr. Ballou in the "Amer. Journ. of Med. Sci.," Jan. 1852.

* "Medical Gazette," Jan. 1847.

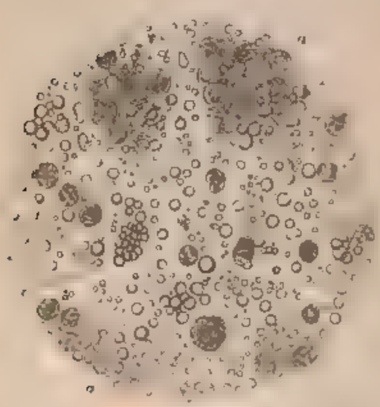
† See the case described by the Bishop of Cork, in the "Philosophical Transactions," vol. xli. p. 813; one mentioned by Sir John Franklin ("Narrative of a Journey to the Polar Sea," p. 157); and one which fell under the notice of the celebrated traveller Humboldt ("Personal Narrative," vol. iii. p. 58).

‡ "Human Physiology," 7th edit., vol. ii. p. 514.—Dr. Dunglison also mentions that in the winter of 1849-50, an athletic man, twenty-two years of age, presented himself at the Jefferson Medical College at Philadelphia, whose left mamma, *without any assignable cause*, had become greatly developed, and secreted milk copiously. It may be added that a lactescent fluid, apparently presenting the characters of true milk, may frequently be expressed from the mammary glands of infants. (See "Dublin Medical Press," April 17, 1850.)

the butter melted at the temperature of 180°, when the casein will fall to the bottom, leaving the butter pure and much less liable to change. The milk, after the cream has been removed, still contains the greatest part of its casein and sugar. If it be kept long enough, a spontaneous change takes-place in its composition; the sugar is converted into lactic acid, and this coagulates the casein, precipitating it in small flakes. The same precipitation may be accomplished at any time, by the addition of an acid; all the acids, however, which act upon albumen, do not precipitate casein, as will presently be pointed-out in detail; the most effectual is that contained in the dried stomach of a calf, known as *rennet*. The whey left after the curd has been separated, contains a large proportion of the saccharine and saline matter that entered into the original composition of the milk; this may be readily separated by evaporation.

921. When Milk is examined with the Microscope, it is seen to contain a large number of particles of irregular size and form, suspended in a somewhat turbid fluid (Fig. 149); these particles vary in size from about the 1-12,700th to the 1-3040th of an inch; and they are termed 'milk-globules.' They are not affected by the mere contact of ether or alkalies; but if these reagents are shaken with them, an immediate solution is the result. The same effect happens, if they are first treated with acetic acid. Hence it is evident, that the globules consist of oily matter, inclosed in an envelope of some kind; and an extremely delicate pellicle may, in fact, be distinguished, after the removal of the oily matter by ether, or after the globules have been ruptured and their contents pressed-out by rubbing a drop of milk between two plates of glass. No proof of the organization of this pellicle has, however, been detected; and it is probably to be regarded as the simple result of the contact of oil with albuminous matter.—Besides these milk globules, other globules of much smaller size are seen in milk; and these present the peculiar movement which is exhibited by molecules in general. Most of them seem to consist of oily matter not inclosed in an envelope, as they are at once dissolved when the fluid is treated with ether; but, according to the statements of Donné, it would seem that a portion of them are composed of casein, suspended, not dissolved, in the fluid. In addition to the foregoing particles, there are found in the *Colostrum*, or milk first secreted after delivery, large yellow granulated corpuscles (Fig. 149, *a, a*), which seem to be composed of a multitude of small grains aggregated together; these appear to be chiefly of a fatty nature, being

Fig. 149.



Microscopic appearance of *Human Milk*, with an intermixture of Colostric corpuscles at *a, a*, and elsewhere.

for the most part soluble in ether; but traces of some adhesive matter, probably mucus, holding-together the particles, are then seen. They are considered by some as 'exudation-corpuscles,' to which they certainly bear a close resemblance; according to Reinhardt, they are transformations of the epithelial cells of the mammary ducts, the result of a sort of fatty degeneration or regressive metamorphosis consequent upon the peculiar activity of the mammary gland during pregnancy.* Lamellæ of epithelium are also found in the milk. —All the larger globules may be removed by repeated filtration; and the fluid is then nearly transparent. This, in fact, is the simplest way of separating the oleaginous from the other constituents of the milk; as but little casein then adheres to the former. The transparent fluid which has passed through the filter, contains nearly the whole amount of the casein of the milk; but even in this fluid there are found globules too minute to be kept back by the filter, whose chemical reactions mark them as casein.

922. We shall now consider the chemical characters of each of the foregoing ingredients.—The *Oleaginous* matter of milk principally consists of the ordinary components of fat; but it also contains another substance peculiar to it, designated as *butyrin*, to which the peculiar smell and taste of butter are due; this yields in saponification three volatile acids, of strong animal odour, to which Chevreul has given the names of butyric, caproic, and capric acids. These peculiar acids are not only formed when the butyrin is treated with alkalies; but are produced by the ordinary decomposition of this principle, which is favoured by time and moderate warmth.—The *Casein* of Human milk, however, is usually said to be much less precipitable by acids, than is that of the Cow; very commonly resisting the action of the mineral acids, and even that of the acetic; but being always coagulated by rennet, though the curd is long in collecting. On this point, however, there has been much discrepancy of statement, on which the recent experiments of Mr. Moore† throw some light. It appears from the results obtained by him, that Human Milk forms with most acids two sets of compounds, one of them soluble in water, the other insoluble; the latter being formed only when the quantity of acid is large in proportion to the casein. Thus, when two fluid *ounces* of Cow's milk were boiled with a single drop of nitric acid, complete coagulation of the casein at once took place; but when two fluid *drachms* of Human milk were treated in the same manner, no coagulation occurred, though the casein was at once thrown-down by a solution of ferrocyanide of potassium; the same quantity of milk, with five drops of the acid, formed a coagulum which was not very manifest until after the lapse of five hours, but was very complete, the serous fluid not being found to contain any casein by testing it with ferrocyanide of potassium; and it required ten drops of nitric acid to produce immediate coagulation. —The quantity of acid necessary to produce coagulation sufficiently rapid to be immediately visible, will vary with the amount of casein present in the particular specimen of milk, 5 drops in some instances producing a coagulation as rapid as that produced by 10 drops in others. In no specimen did Mr. Moore fail to produce coagulation by adding a sufficiency of acid. Acetic acid without heat produces in Human milk

* See an abstract of his views in the "Edinb. Monthly Journal," Feb., 1848.

† "Dublin Quarterly Journal of Medical Science," vol. vii. p. 280

a slow separation of soft flaky coagula; but, when heat is employed, a more perfect coagulation is produced by small, than by large quantities of this acid. Rennet does not seem to act upon the casein of Human milk, unless an acid be also present. In several of these particulars, as well as in its small proportional amount, the Casein of Ass's milk bears a closer resemblance to that of Human milk, than does that of the Cow.—The *Sugar of Milk*, which may be obtained by evaporating whey to the consistence of a syrup, and then setting it aside to crystallize, forms opaque prisms or rhombohedra, whose composition is 10 C, 8 H, 8 O + 2 HO. In many of its properties it bears a close resemblance to Glucose or Gelatin-sugar, into which it is readily converted by the agency of dilute sulphuric or hydrochloric acid, or by the acetic or citric acids. It is readily made to pass into the lactic and butyric fermentation, by the appropriate ferments; but is with difficulty brought to undergo the vinous fermentation.—The *Saline* matter contained in milk, appears to be nearly identical with that of the blood; with a larger proportion of the phosphates of lime and magnesia, which amount to 2 or 2½ parts in 1000. These phosphates are held in solution chiefly by the casein, which seems to have a power of combining with them, even greater than that of albumen: the presence of a minute proportion of free alkali also assists their solution. A small portion of iron in the state of phosphate, together with the chlorides of potassium and sodium, may also be detected in milk.*

923 The proportion of these different constituents is liable to great variation, from several causes. Thus, the whole amount of the solid constituents may vary from 86 to 138·6 parts in 1000, the difference being partly due to individual constitution, but in great part, also, to the amount and character of the ingesta. The average seems to be between 100 and 120 parts. The following are the results of the analyses of Simon; the first column being the average of fourteen observations upon the same woman; the second giving the maximum of each ingredient, and the third the minimum:—

	I.	II.	III.
Water	883·6	914·0	861·4
Butter	25·3	54·0	8·0
Casein	34·3	45·2	19·6
Sugar of Milk and extractive matters	48·2	62·4	39·2
Fixed salts	2·3	2·7	1·6

It also appears from the analyses of Simon, that the proportion of the different ingredients is liable to variation, according to the time which has elapsed since parturition. The quantity of Casein is at its minimum at the commencement of lactation, and then gradually rises until it attains a nearly fixed proportion. The quantity of Sugar, on the contrary, is at its maximum at first, and gradually diminishes. The amount of Butter (as appears from the wide extremes shown in the above tables) is more variable than that of any other constituent.—That some of the variations, moreover, are due to the character of the ingesta, and others to the external temperature, amount of exercise, and other circumstances affecting the individual, is proved by the inquiries of Dr. Playfair upon

* Haidlen in "Annalen der Chemie und Pharmacie," band xlv., p. 163.

the Milk of the Cow. He has shown that the amount of butter depends in part upon the quantity of oily matter in the food, and in part upon the amount of exercise which the animal takes and the warmth of the atmosphere in which it is kept: exercise and cold, by increasing the respiration, eliminate part of the oily matter in the form of carbonic acid and water; whilst rest and warmth, by diminishing this drain, favour its passage into the milk. The proportion of Casein, on the other hand, is increased by exercise. Dr Playfair's experience on this head seems to correspond with the results of common observation in Switzerland; for where the cattle pasture in very exposed situations, and are obliged to use a great deal of muscular exertion, the quantity of butter yielded by them is very small, whilst the cheese is in unusually-large proportion; but these same cattle, when stall-fed, give a large quantity of butter and very little cheese.

924. The change which naturally takes-place from the condition of Colostrum to that of true Milk, during the first week of lactation, is a very important one. The Colostrum has a purgative effect upon the child, which is very useful in clearing its bowels of the meconium that loads them at birth; and thus the necessity of any other purgative is generally superseded. Occasionally, however, the *colostric* character is retained by the milk, during an abnormally long period; and the health of the infant is then severely affected. It is important to know that this may occur, even though the milk may present all the usual appearance of the healthy secretion; but the microscope at once detects the difference.* The return to the character of the early milk, which has been stated to take place after the expiration of about twelve months, seems to indicate that Nature designs the secretion no longer to be encouraged; the mother's milk cannot then be so nutritious to the child as other food;† and every medical man is familiar with the injurious consequences to which she renders herself liable, by unduly prolonging lactation.‡ Cases are not unfrequent, however, in which the secretion continues as long as there is a demand for it; and sometimes quite independently of this. It is the habit, among some nations, to suckle the children until they are three or four years old, and to continue doing so even though another pregnancy should supervene;§ so that the older child is only displaced by the arrival of another infant. And it seems to be chiefly among those who have thus forced the mammary gland into a state of unnaturally persistent activity, that the spontaneous and irrepressible flow continues, after the demand for it has ceased.||

925. It is very interesting to observe that Milk contains the three

* See Donné, "Du Lait, et en particulier celui des Nourrices," and "Brit. and For Med. Review," vol. vi. p. 181.

† On the whole subject of Infant Nutrition, the Author would strongly recommend the excellent Little work of Dr. A. Combe, formerly referred to.

‡ One of these, which has particularly fallen under the Author's notice, is debility of the retina, sometimes proceeding to complete amaurosis; this, if treated in time, is most commonly relieved by discontinuance of lactation, generous diet, and quinine.

§ See Erman's "Travels in Siberia" (translated by Cooley), vol. ii. p. 527, and the "Narrative of the United States' Exploring Expedition," vol. ii. p. 138.

|| Thus Dr. Green has published ("New York Journ. of Med. and Surg.," Sept. 1844) the case of a lady, æt. 47, the mother of four children, who had an abundant supply of milk for *twenty-seven years* previously. A period of exactly four years and a half occurred between each birth, and the children were permitted to take the breast until

classes of principles which are required for human food,—the Albuminous, the Oleaginous, and the Saccharine; and it is the only secreted fluid in which these all exist to any considerable amount. It is, therefore, the food most perfectly adapted for the young animal; and is the only single article supplied by nature, in which such a combination exists. Our artificial combinations will be suitable to replace it, just in proportion as they imitate its character; but in none of them can we advantageously dispense with milk, under some form or other. It should be remembered that the Saline ingredients of milk, especially the phosphates of lime, magnesia, and iron, have a very important function in the nutrition of the infant, affording the material for the consolidation of its bones and for the production of its red blood-corpuscles, and any fluid substituted for milk, which does not contain these, is deficient in essential constituents. It is very justly remarked by Dr. Rees,* that, of all the secreted fluids, Milk is most nearly allied in its composition to Blood.

926. The proportion of the different ingredients in the Milk of different animals, is subject to considerable variation: and this fact is of much practical importance in guiding our selection, when good Human milk cannot be conveniently obtained for the nourishment of an infant. The first point to be inquired-into, is the quantity of solid matter contained in each kind, this may be determined either by evaporation, or by the specific gravity of the fluid. The Specific Gravity of Human milk is stated by Dr. Rees (loc cit.) to vary between 1030 and 1035, others, however, have estimated it much lower. That of the Cow appears to be usually about the same; that of the cream, however, being 1024, and that of the skimmed-milk about 1035. The variation will in part depend (as in the case of the urine) upon the quantity of fluid ingested, and in part, it is probable, upon the manner in which the milk is drawn; for it is well known to milkers, that the last milk they obtain is much richer than that with which the udder is distended at the commencement. The quantity of solid matter obtainable from Cow's Milk by evaporation, seems to be usually considerably greater than that yielded by Human Milk; and there is also a considerable difference in the relative proportions of their ingredients, there being far more casein and less sugar in the milk of the Cow, than in that of the Human female. The following table exhibits the average proportions of the different ingredients in the Milk of various animals from which that fluid is commonly obtained, these proportions, however, are liable to wide variations.

	Woman. (Simon.)	*Cow* (Simon.)	*Goat.* (Chevallier.)	*Sheep* (Chevallier.)	*Ass* (Simon.)	*Mare* (Lassaigne.)
Water . .	890	860	868	856	907	888
Solids .	110	140	132	144	95	112
Butter . .	25	38	33	42	12	8
Casein . .	35	68	40	45	16	16
Sugar and Extractive	48	30	53	50	65	88
Fixed Salts . . .	2	6	6	7		

they were running about at play. At the time when Dr. G. wrote, she had been nine years a widow, and was obliged to have her breasts drawn daily, the secretion of milk being so copious.

* "Cyclopædia of Anatomy and Physiology," Art. 'Milk.'

It appears from this, that, whilst the milks of the Cow, Goat, and Sheep have a general correspondence with each other, those of the Ass and Mare are fluids of very dissimilar character, containing a comparatively small proportion of casein, and still less butter, but abounding in sugar. Hence it is, that they are much more disposed to ferment than other milk; indeed the sugar of Mare's milk is so abundant, that the Tartars prepare from it a spirituous liquor, to which they give the name of *koumiss*. Although no milk more nearly approaches that of the Human female, in the proportion of its ingredients, than that of the Goat, its casein forms a peculiarly-dense curd, which does not suit the stomach of the infant; besides which, the milk is tainted with the peculiar odour of the animal, which is more intense if the individual be dark-coloured. The milk of the Ass, though differing in the proportion of its ingredients, seems to bear a closer approximation in properties (§ 922). The milk of the Cow will usually answer very well for the food of the infant, if care be taken to dilute it properly, according to the age of the child, and to add a little sugar. Where there is an apprehension of an early failure in the supply of Milk, the Author has found it advantageous to commence feeding the infant once a day with this mixture, soon after the first month; the number of its meals may be progressively increased, until it becomes entirely independent of its parent, without any abrupt transition; and at the same time the proportion of water and of sugar may be diminished, in accordance with the natural change which takes place in the milk of the mother during the progress of lactation (§ 923).

927. From what has been stated of the close correspondence between the elements of the Blood and those of the Milk, it is evident that we can scarcely expect to trace the existence of the latter, as such, in the circulating fluid. To what degree the change in which their elaboration consists, is accomplished in the Mammary gland, or during the course of the circulation, there is no certain means of ascertaining. It is evident that the secretion cannot serve as the channel for the deportation of any element, the accumulation of which would be injurious to the system; since it does not occur in the Male at all, and is present in the Female at particular times only. Yet there is reason to believe that if, whilst the process is going on, it be suddenly checked, the retention of the material in the blood, or the re-absorption of the secreted fluid, is attended with injurious consequences. Thus if, when the milk is first secreted, the child be not put to the breast, an accumulation takes place, which, if not relieved, occasions great general disturbance of the system. The narrowness of the orifices of the milk-tubes obstructs the spontaneous exit of the fluid, especially in *primaparæ;* the reservoirs and ducts become loaded; further secretion is prevented; and a state of congestion of the vessels of the gland, tending to inflammation, is induced. The accompanying fever is partly due, no doubt, to the local disturbance; but in part also, there seems reason to believe, to the re-absorption of the milk into the blood; this cannot but be injurious, since, although but little altered, the constitution of milk is essentially different, especially in regard to the quantity of crystallizable matter (sugar) which it contains. —Cases of the *vicarious* secretion of milk are not numerous, and in no instance is there any proof that the elements of the fluid were pre-existent in the blood. Some of the most curious are those in which it

has been poured-out from a gland in the groin; but it is probable that this was in consequence of the existence of a real repetition, in that place, of the true mammary structure; this being the situation of the mammæ in many of the inferior animals, of which the homologues in Man are usually undeveloped.*

928. Of the quantity of Milk ordinarily secreted by a good Nurse, it is difficult to form a correct estimate;† since the amount which can be artificially drawn, affords no criterion of that which is secreted at the time of the 'draught' (§ 833). The quantity which can be squeezed from either breast at any one time, and which, therefore, must have been contained in its tubes and reservoirs, is about two ounces. The amount secreted is greatly influenced by the mental and physical condition of the female, and also by the quantity and character of the ingesta. In regard to the influence of the mental state upon this secretion, ample details have already been given (§§ 833, 919). With respect to the physical state most favourable to the production of an ample supply of this important fluid, it may be stated generally, that sound health, a vigorous but not plethoric constitution, regular habits, moderate but not fatiguing exercise, and an adequate but not excessive amount of nutritious food, furnish the conditions most required. It is seldom that stimulating liquors, which are so commonly indulged-in, are anything but prejudicial; and even where, as sometimes unquestionably happens, an improvement in the condition both of mother and infant is the immediate result of the moderate employment of them, it is questionable whether the remote effect is not of a reverse nature.‡ Their *modus operandi*, when they are

* The following is a more unequivocal case of vicarious secretion, and it is peculiarly interesting as exhibiting the injurious effects of the re-absorption of the secretion, and the relief which the system experienced when it was separated from the blood by the new channel. "A lady of delicate constitution (with a predisposition to pneumonia) was prevented from suckling her child, as she desired, by the following circumstance. Soon after her delivery she had a severe fever, during which her breasts became very large and hard, the nipples were swollen and firm, and there was evidently an abundant secretion of milk; but neither the sucking of the infant, nor any artificial means, could draw a single drop of fluid from the swollen glands. It was clear that the milk-tubes were closed; and as the breasts continued to grow larger and more painful, purgatives and other means were employed to check the secretion of milk. After three days, the fever somewhat diminished, and was replaced by a constant cough, which was at first dry, but soon after was followed by the expectoration of simple mucus. After this, the cough diminished in severity, and the expectoration became easy; but the sputa were no longer mucous, but were composed of a liquid, which had all the physical characters of genuine milk. This continued for fifteen days; the quantity of milk expectorated amounting to three ounces or more in the twenty-four hours. The breasts gradually diminished in size, and by the time that the expectoration ceased, they had resumed their natural dimensions. The same complete obstacle to the flow of milk from the nipples recurred after the births of four children successively, with the same sequelæ. After the sixth she had the same symptoms of fever, but this time they were not followed by bronchitis or the expectoration of milk; she had in their stead copious sweatings, which, with other severe symptoms, reduced her to a cachectic state, and terminated fatally in a fortnight." ("Bulletino delle Scienze Mediche," Apr., 1839, and "Brit. and For. Med. Review," Jan., 1540.)

† For an estimate by M. Guillot, founded on the comparative weight of the Infant before and after lactation, see "L'Union Medicale," 1852, No. 16. The total amount considered by Mons. G. to be usually drawn in the twenty-four hours, varies from 3[illegible] to 64 oz. (apoth.), but his estimates are vitiated by the extraordinary frequency of the lactations observed, the infant being put to the breast from 25 to 30 times in the twenty-four hours.

‡ See the Author's "Physiology of Temperance and Total Abstinence," § 208.

really beneficial, seems to lie in promoting the digestive process, and in thus aiding in the appropriation of those nutritive materials, which constitute the real source of the solid constituents of the milk.

929. The influence of various Medicines upon the Milk, is another important question which has not yet been sufficiently investigated. As a general rule, it appears that most soluble saline compounds pass into the milk as into other secretions; but there are many exceptions. Common salt, the sesqui-carbonate of soda, sulphate of soda, iodide of potassium, oxide of zinc, tris-nitrate of bismuth, and sesqui-oxide of iron, have been readily detected in the milk, when these substances were experimentally administered to an Ass; and ordinary experience shows that the Human infant is affected by many of these, when they are administered to the mother. The influence of mercurial medicines taken by the mother, in removing from the infant a syphilitic taint possessed by both, is also well known. The vegetable purgatives, especially castor-oil, senna, and colocynth, have little effect upon the milk; hence they are to be preferred to the saline aperients, when it is not desired to act upon the bowels of the child.

CHAPTER XVII.

OF THE DIFFERENT BRANCHES OF THE HUMAN FAMILY, AND THEIR MUTUAL RELATIONS.

1. *General Considerations.*

930. Amongst the various tribes of Men, which people the surface of the globe, and which are separated from all other animals by the characters formerly described (Chap. I.), there are differences of a very striking and important nature. They are distinguishable from each other, not only by their language, dress, manners and customs, religious belief, and other acquired peculiarities, but by the physical conformation of their bodies; and the difference lies not merely in the colour of the skin, the nature of the hair, the form of the soft parts (such as the nose, lips, &c.), but in the shape of the skull, and of other parts of the bony skeleton, which might be supposed to be less liable to variation. It is a question of great scientific interest, as well as one that considerably affects the mode in which we regard the races that differ from our own, whether they are all of *one species*, that is, descended from the *same* or from *similar* parentage,—or whether they are to be considered as *distinct species*, the first parents of the several races having had the same differences among themselves, as those which are now exhibited by their descendants.

931. In order to arrive at a just conclusion on this subject, it is necessary to take a very extensive survey of the evidence furnished by a number of different lines of inquiry. Thus, in the First place, it is right to investigate what are the discriminating structural marks, by which *species* are distinguished among other tribes of animals.—Secondly, it should be ascertained to what extent *variation* may proceed among races which are historically known to have had a common parentage, and what are the circumstances which most favour such variations.—Thirdly, the

extreme variations, which present themselves among the different races of Men, should be compared with those which occur among tribes of animals known to be of the same parentage; and it should be questioned, at the same time, whether the circumstances which favour the production of varieties in the latter case, are in operation in the former.—Fourthly, where it is impossible to trace-back distinct races to their origin, it is to be inquired how far agreement in physiological and psychological peculiarities may be regarded as indicating specific identity, even where a considerable difference exists in bodily conformation; and this test, if it can be determined-on, has to be applied to Man.—Fifthly, it must be attempted, by a detailed examination of the varieties of the Human race themselves, to ascertain whether their differences in conformation are constant; or whether there are not such occasional manifestations, in each race, of a tendency to assume the characters of others, as to prevent any definite lines being drawn between the several tribes, which together make-up the (supposed) distinct species.—An investigation so comprehensive could not be followed-out, even in the most cursory manner that would be consistent with utility, within the limits of the present work; and no more will be attempted, therefore, than an indication of the principal points of difference among the several Races of Men, and a statement of the results of inquiry into their degree of constancy in each of the principal groups which they have been thought to mark-out.*

932. The differential characters on which those have relied, who have sought to establish the existence of a *plurality of species* among Mankind, are both Anatomico-Physiological, and Psychological. Under the former head rank the Colour of the Skin, the texture of the Hair, and the conformation of the bony Skeleton, especially the Skull. The latter consist in the superiority claimed for some races over others, in Intellectual power, and in Moral and Religious capacity. The former group will be the one first considered.

933. The *Colour* of the skin exists in the Epidermis only; and it depends upon the admixture of *pigment-cells* with the ordinary epidermic cells (PRINC. OF GEN. PHYS.); all the varied hues presented by the different races of men, being due to the relative amount of these cells, and to the particular tint of the pigment which they form. It would be easy, by selecting well-marked specimens of each race, to make it appear that colour affords a character sufficiently distinctive for their separation; thus, for example, the fair and ruddy Saxon, the jet-black Negro, the olive Mongolian, and the copper-coloured North American, might be considered to be positively separated from each other by this character,—propagated, as it seems to be, with little or no perceptible change, from generation to generation. But although such might appear to be the clear and obvious result of a comparison of this kind, yet a more careful and comprehensive survey tends to break-down the barrier that would be thus

* The whole of this investigation has been most elaborately, and in the Author's opinion most successfully worked out by Dr. Prichard, in his profound and philosophical Treatise on the "Physical History of Man." For a more concise view of Dr. Prichard's argument, with some additional considerations not embraced in it, the Author may refer to his own Article on the 'Varieties of the Human Species,' in the "Cyclop. of Anat. and Phys.," vol. iv. See also Dr. R. G. Latham's "Natural History of the Varieties of Man," and his shorter essay on the 'Varieties of the Human Species,' in Orr's "Circle of the Sciences," vol. i.

established. For, on tracing this character through the entire family of Man, we find the isolated specimens just noticed to be connected by such a series of links, and the transition from one to the other to be so very gradual, that it is impossible to say where the lines are to be drawn between them. There is nothing here, then, which at all approaches to those fixed and definite marks, that are always held to be requisite for the establishment of specific distinctions among other tribes of animals.

934. But further, there is abundant evidence that these distinctions are far from being constantly maintained, even in any one race. For among all the principal subdivisions, *albinoism*, or the absence of pigment-cells, occasionally presents itself, so that the fair skin of the European may present itself in the offspring of the Negro or of the Red Man.* On the other hand, instances are by no means rare, of the unusual development of pigment-cells in individuals of the fair-skinned races; so that parts of the body are of a dark red or brown hue, or are even quite black. Such modifications may seem of little importance to the argument; since they are confined to individuals, and may be put aside as accidental. But there is ample evidence that analogous changes may take place in the course of time, which tend to produce a great variety of shades of colour, in the descendants of any one stock. Thus, in the great Indo-European family (part of the *Caucasian* race of Blumenbach), which may be unquestionably regarded as having had a common origin, we find tribes with fair complexion, yellow hair, and blue eyes,—others presenting the xanthous or olive hue,—and others decidedly black. A similar diversity may be seen among the American races, which are equally referable to one common stock; and it exists to nearly the same extent among the African nations, which appear to be similarly related to each other. It may be freely admitted that, among European colonists settled in hot climates, such changes do not present themselves within a few generations; but in many well known instances of earlier colonization, they are very clearly manifested. Thus the wide dispersion of the Jewish nation, and their remarkable isolation (maintained by their religious observances) from the people among whom they live, render them peculiarly appropriate subjects for such observations; and we accordingly find that the brunette complexion and dark hair, which are usually regarded as charac-

* A very curious example of *change of colour* in a Negro, has been recently recorded on unquestionable authority. The subject of it is a negro slave in Kentucky, æt. 45, who was born of black parents, and was himself perfectly black until 12 years of age. At that time, a portion of the skin, an inch wide, encircling the cranium just within the edge of the hair, gradually changed to white; also the hair occupying that locality. A white spot next appeared near the inner canthus of the left eye, and from this the white colour gradually extended over the face, trunk, and extremities, until it covered the entire surface. The complete change from black to white occupied about ten years; and but for his hair, which was crisped or woolly, no one would have supposed at this time that his progenitors had offered any of the characteristics of the Negro, his skin presenting the healthy vascular appearance of that of *a fair complexioned* European. When he was about 22 years of age, however, dark *copper-coloured* or brown spots began to appear on the face and hands; but these have remained limited to the portions of the surface exposed to light. About the time that the black colour of his skin began to disappear, he completely lost his sense of smell (§ 743 *note*); and since he has become white, he has had measles and hooping cough a second time. (See Dr. Hutchinson's account of this case, in the "Amer. Journ. of Med. Sci.," Jan., 1852.) A case of partial disappearance of the black colour of the Negro's Skin was brought by Dr. Inman before the Zoological Section of the British Association at Liverpool, Sept., 1854.

teristic of that race, are frequently superseded, in the Jews of Northern Europe, by red or brown hair and fair complexion; whilst the Jews who settled in India some centuries ago, have become as dark as the Hindoos around them.

935. The relation of the complexions of the different races of Men to the climates they respectively inhabit, is clearly established by an extended comparative survey of both. From such a survey the conclusion is inevitable, that the intertropical region of the earth is the principal seat of the darkest races of Men; whilst the region remote from the tropics is that of the fairer races; and that the climates approaching the tropics are generally inhabited by nations which are of an intermediate complexion. To this observation it may be added, that high mountains, and countries of great elevation, are generally inhabited by people of a lighter colour than are those of which the level is low, such as swampy or sandy plains upon the sea-coast. These distinctions are particularly well seen in Africa, where the tropics almost exactly mark out the limits of the black complexion of the inhabitants; and where the deepest hue is to be seen among the Negroes of the Guinea Coast, whose residence unites both the conditions just mentioned; whilst the mountainous regions in their immediate vicinity are inhabited by tribes of a much lighter aspect.

936. The nature of the *Hair* is, perhaps, one of the most permanent characteristics of different races. In regard to its colour, the same statements apply, as those just made with respect to the colour of the skin, the variety of hue being given by pigment-cells, which may be more or less developed under different circumstances. But it has been thought that its *texture* afforded a more valid ground of distinction; and it is commonly said, that the substance which grows on the head of the African races, and of some other dark-coloured tribes (chiefly inhabiting tropical climates), is *wool*, and not hair. This, however, is altogether a mistake; for microscopic examination clearly demonstrates, that the hair of the Negro has exactly the same structure with that of the European, and that it does not bear any resemblance to wool, save in its crispness and tendency to curl. Moreover, even this character is far from being a constant one; for, whilst Europeans are not unfrequently to be met with, whose hair is nearly as crisp as that of the Negro, there is a great variety amongst the Negro races themselves, which present every gradation from a completely-crisp (or what is termed woolly) hair, to merely curled or even flowing locks.* A similar observation holds-good in regard to the natives of the islands of the great Southern Ocean, where some individuals possess crisp hair, whilst others, of the same race, have it merely curled.—It is evident, then, that no characters can be drawn from the colour or texture of the hair in Man, sufficiently fixed and definite to serve for the distinction of races; and this view is borne-out by the evident influence of climate, in producing changes in the hairy covering of almost every race of domestic animals; such changes often manifesting

* It is a very common mistake, especially in the United States, to consider *Negro* as synonymous with *African*. So far is this from being the fact, that, as Dr Latham justly remarks, "the true Negro area, the area occupied by men of the black skin, thick lips, and woolly hair, is exceedingly small, as small in proportion to the rest of the continent, as the area of the district of the stunted Hyperboreans is in Asia, or that of the Lapps in Europe." (See §§ 955, 956.)

themselves in the very individuals that have been transported from one country to another, and yet more distinctly in succeeding generations.

937. It has been supposed that varieties in the configuration of the *Skeleton* would afford characters for the separation of the Human races, more fixed and definite than those derived from differences in the form, colour, or texture of the soft parts which clothe it: and attention has been particularly directed to the *skull* and the *pelvis*, as affording such characters. It has been generally laid-down as a fundamental principle, that all those nations which are found to resemble each other in the shape of their heads, must needs be more nearly related to each other, than they are to tribes of Men which differ from them in this particular. But if this principle be rigorously carried-out, it will tend to bring together races which inhabit parts of the globe very remote from each other, and which have no other mark of affinity whatever: whilst, on the other hand, it will often tend to separate races which every other character would lead us to bring together. It is to be remembered, moreover, that the varieties in the conformation of the skeleton, presented by the breeds of domesticated animals, are at least equal to those which are manifested in the conformation and colour of their soft parts; and we might reasonably expect, therefore, to meet with similar variations among the Human races. It is probable, however, that climate has not so much influence in producing such changes in the configuration of the body, as the peculiar habits and mode of life of the different races; and Dr. Prichard has pointed-out a very remarkable relation of this kind, in regard to the three principal types of form presented by the Skull.

938. Among the rudest tribes of Men, hunters and savage inhabitants of forests, dependent for their supply of food on the accidental produce of the soil or on the chase,—among whom are the most degraded of the African nations, and the Australian savages,—a form of head is prevalent,

FIG. 150.

Profile and basal views of the *Prognathous Skull* of a Negro.

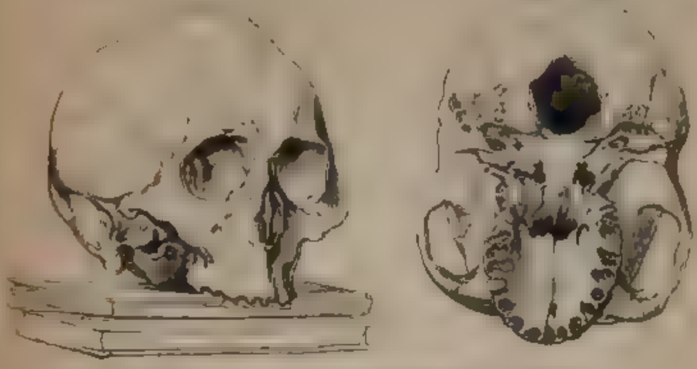
which is most aptly distinguished by the term *prognathous*, indicating a prolongation or forward-extension of the jaws (Fig. 150). This character is most strongly marked in the Negroes of the Gold Coast, whose skulls are usually so formed as to give the idea of lateral compression. The

temporal muscles have a great extent, rising high on the parietal bones the cheek-bones project forward, and not outward, the upper jaw is lengthened and projects forwards, giving a similar projection to the alveolar ridge and to the teeth, and the lower jaw has somewhat of the same oblique projection, so that the upper and lower incisor teeth are set at an obtuse angle to each other, instead of being nearly in parallel planes, as in the European. From the shape of the upper jaw alone would result a marked diminution in the facial angle, measured according to the method of Camper, but this diminution is far from being sufficient to approximate the Ethiopian races to the higher Apes, as some have supposed it to be (§ 8). Independently of the diminution of the facial angle, resulting from the projection of the upper jaw, it is quite certain that, in the typical prognathous skull, there is a want of elevation of the forehead; but it does not appear that there is a corresponding diminution in the capacity of the cranial cavity, the retreating form of the forehead being partly due to the general elongation of the skull in the antero-posterior direction. Nor is it true, as stated by some, that the position of the foramen magnum in the Negro is decidedly behind that which it holds in the European, in this respect approaching that of the Apes (§ 2): since, if due allowance be made for the projection of the upper jaw, this aperture is found to have the same position in the prognathous skull as in the oval one, namely, exactly behind the transverse line bisecting the antero-posterior diameter of the base of the cranium. The prognathous skull is further remarkable for the large development of the parts connected with the organs of sense, especially those of smell and hearing. The aperture of the nostrils is very wide, and the internal space allowed for the distribution of the olfactory nerve, is much larger than in most European heads; the posterior openings of the nasal cavity are not less remarkable for their width, than the anterior. The external auditory meatus is also peculiarly wide and spacious, and the orbital cavities have been thought to be of more than ordinary capacity,—but this last is by no means a constant character.

939. A second type of cranial conformation, very different from the preceding, belongs principally to the Nomadic races, who wander with their herds and flocks over vast plains, and to the tribes who creep along the shores of the Icy Sea, and live partly by fishing, and in part on the flesh of their reindeer. This form, designated by Dr. Prichard as the *pyramidal* (Fig. 151), is typically exhibited by various nations of Northern and Central Asia; and is seen, in an exaggerated degree, in the Esquimaux. Its most striking character is the lateral or outward projection of the zygoma, which is due to the form of the malar bones. These do not project forwards and downwards under the eyes, as in the prognathous skull, but take a lateral or outward direction, forming, with the zygomatic process of the temporal bone, a large rounded sweep or segment of a circle. From this, in connection with the narrowness of the forehead, it results, that lines drawn from the zygomatic arches, touching the temples on either side, instead of being parallel (as in Europeans), meet over the forehead, so as to form with the basis a triangular figure. The upper part of the face being remarkably flat, the nose also being flat, and the nasal bones, as well as the space between the eyebrows, being nearly on the same plane with the cheek-bones, the triangular space bounded by

these lines may be compared to one of the faces of a pyramid. The orbits are large and deep; and the peculiar conformation of the bones which

Fig. 151



Front and basal views of the *Pyramidal Skull* of an Esquimaux

surround it, gives to the aperture of the lids an apearance of obliquity, the inner angle seeming to be directed downwards. The whole face, instead of presenting an oval form, as in most Europeans and Africans, is of a lozenge-shape. The greater relative development of the zygomatic bones, and of the bones of the face altogether, when compared with the capacity of the cranium, indicates in the pyramidal skull a more ample extension of the organs subservient to sensation; the same effect being thus produced by lateral expansion, as by the forward extension of the facial bones in the prognathous skulls.

940. The most civilized races,—those which live by agriculture and the arts of cultivated life,—all the most intellectually-improved nations of Europe and Asia,—have a shape of the head which differs from both the preceding, and which may be termed *oval or elliptical*. This at once approves itself as a more symmetrical form; no part having an excessive prominence, whilst, on the other hand, there is nowhere an appearance of undue flattening or compression. The head is altogether of a rounder shape than in the other varieties, and the forehead is more expanded, while the maxillary bones and the zygomatic arches are so formed, as to give the face an oval shape, nearly on a plane with the forehead and cheek-bones, and

Fig. 152.

Oval Skull of a European.

not projecting towards the lower part. Owing to the more perpendicular direction of the alveolar processes, the front teeth are fixed in planes which are nearly or quite parallel to each other. The principal features in this form of cranium are thus of a negative character; the chief positive distinction is the large development of the cranial cavity, and especially the fulness and elevation of the forehead, in proportion to the size of the face;—indicating the predominance of the intellectual powers, over those merely instinctive propensities which are more directly connected with sensations. Among European nations, the Greeks have probably displayed the greatest symmetry and perfection in the form of the head; but various departures may be traced towards the preceding forms, when we compare the crania of different races, and even of individuals, belonging to the same stock,—some approaching the pyramidal form of the Northern Asiatics, whilst others approximate to the prognathous type of the Negro.

941. The influence of habits of life, continued from generation to generation, upon the form of the head, is remarkably evinced by the transition from one type to another, which may be observed in nations that have undergone a change in their manners and customs, and have made an advance in civilization. Thus, to mention but one instance, the Turks at present inhabiting the Ottoman and Persian empires, are undoubtedly descended from the same stock with those nomadic races which are still spread through Central Asia (§ 953). The former, however, having conquered the countries which they now inhabit, eight centuries since, have gradually settled down to the fixed and regular habits of the Indo-European race, and have made corresponding advances in civilization; whilst the latter have continued their wandering mode of life, and can scarcely be said to have made any decided advance during the same interval. Now the long-since-civilized Turks have undergone a complete transformation into the likeness of Europeans; whilst their nomadic relatives retain the pyramidal configuration of the skull in a very marked degree. Some have attributed this change in the physical structure of the Turkish race, to the introduction of Circassian slaves into the harems of the Turks; but this could only affect the opulent and powerful amongst the race; and the great mass of the Turkish population have always intermarried among themselves. The difference of religion and manners must have kept them separate from those Greeks whom they subdued in the new Ottoman countries; as in Persia, the Tajiks, or real Persians, still remain quite distinct from their Turkish rulers, belonging to a different sect among the Mussulmans, and commonly living apart from them.—In like manner, even the Negro head and face may become assimilated to the European, by long subjection to similar influences; thus, in some of our older West Indian Colonies, it is not uncommon to meet with Negroes, the descendants of those first introduced there, who exhibit a very European physiognomy; and it has even been asserted that a Negro belonging to the Dutch portion of Guiana may be distinguished from another belonging to the British settlements by the similarity of the features and expression of each, to those which respectively characterize his masters. The effect could not be here produced by the intermixture of bloods, since this would be made apparent by alteration of colour.—But not only may the pyramidal and progna-

thous types be elevated towards the elliptical; the elliptical may be degraded towards either of these. Want, squalor, and ignorance, have a special tendency to induce that diminution of the cranial portion of the skull, and that increase of the facial, which characterize the prognathous type; as cannot but be observed by any one who takes an accurate and candid survey of the condition of the most degraded part of the population of the great towns of this country, but as is seen to be pre-eminently the case with regard to the lowest classes of Irish immigrants.* A certain degree of retrogression to the pyramidal type, is also to be noticed among the nomadic tribes which are to be found in every civilized community. Among these, as has been remarked by a very acute observer,† "According as they partake more or less of the purely vagabond nature, doing nothing whatsoever for their living, but moving from place to place, preying on the earnings of the more industrious portion of the community, so will the attributes of the nomade races be found more or less marked in them; and they are all more or less distinguished for their high cheek-bones and protruding jaws;" thus showing that kind of mixture of the pyramidal with the prognathous type, which is to be seen among the lowest of the Indian and Malayo-Polynesian races.

942. Next to the characters derived from the form of the head, those which are founded upon the form of the *pelvis* seem entitled to rank. These have been particularly examined by Professors Vrolik and Weber. The former was led by his examinations of this part of the skeleton, to consider that the pelvis of the Negress, and still more that of the female Hottentot, approximates to that of the Simiæ in its general configuration; especially in its length and narrowness,—the iliac bones having a more vertical position, so that the anterior spines approach one another much more closely than they do in the European; and the sacrum also being longer and narrower. On the other hand, Prof. Weber‡ concludes, from a more comprehensive survey, that no particular figure is a permanent characteristic of any one race. He groups the principal varieties which he has met-with, according to the form of the upper opening, into oval, round, four-sided, and wedge-shaped. The first of these is most frequent in the European races; the second, among the American races; the third, most common among the Mongolian nations, corresponds remarkably with their form of head; whilst the last chiefly occurs among the races of Africa, and is in like manner conformable with the oblong compressed form usually presented by their cranium. But although there are particular shapes which are most prevalent in each race, yet there are numerous individual deviations, of such a nature that every variety of form presents itself occasionally in any given race.

943. Other variations have been observed by anatomists, between the different races of Man, in the relative length of the bones, and in the shape of the limbs; but these also seem to have reference to the degree of civilization, and to the regularity of the supply of wholesome

* See the "Dublin University Magazine," No. xlviii.

† Mr. Henry Mayhew, in "London Labour and the London Poor," p. 2.

‡ "Die Lehre von den Ur- und Racenformen der Schaedel und Becken des Menschen;" Dusseldorf, 1830

nutriment. It is generally to be observed that the races least improved by civilization, like the uncultivated breeds of animals, have slender, lean, and elongated limbs; this may be especially remarked in the natives of Australia. In nearly all the less civilized races of Men, the limbs are more crooked and badly formed than the average of those of Europeans; and this is particularly the case in the Negro, the bones of whose legs bow outwards, and whose feet are remarkably flat. It has been generally believed, that the length of the fore-arm in the Negro is so much greater than in the European, as to constitute a real character of approximation to the Apes. The difference, however, is in reality extremely slight; and is not at all comparable with that which exists between the most uncultivated races of Men and the highest Apes (§ 5). And in regard to all the peculiarities here alluded-to, it is to be observed, that they can only be discovered by the comparison of large numbers of one race with corresponding numbers of another; for individuals are found in every tribe, possessing the characters which distinguish the majority of the other race. Such peculiarities, therefore, are totally useless as the foundation of *specific* characters; being simply variations from the ordinary type, resulting from causes which might affect the entire race, as well as individuals. The connection between the general form of the body, on the one hand, and the degree of civilization (involving the regular supply of nutriment) on the other, is made apparent, not merely by the improvement which we perceive in the form, development, and vigour of the frame, as we advance from the lowest to the most cultivated of the Human races, but also by the degradation that is occasionally to be met-with in particular groups of the higher tribes, which have been subjected for several generations to the influence of depressing causes. Of such degradation, occurring under circumstances that permit its successive steps to be traced, we have a remarkable example in the conversion of certain tribes of the Hottentot race into Bushmen (§ 958); and there is very strong ground for the belief, that similar influences have operated at a more remote period, in the production of the peculiar characters of the Guinea-coast Negroes and Australian Bushmen.

944. Independently, however, of the obvious modifying influence of external circumstances, much allowance must be made for that *tendency to variation*, which presents itself, more or less, in all those races of animals, which possess such a constitutional capability of adaptation to changes in climate, habits of life, &c., as enables them to live and flourish under a variety of conditions. Thus we find that the offspring of any one pair of domesticated animals do not all precisely agree among themselves, or with their parents, either in bodily conformation, or in psychical character; but that *individual* differences, as they are termed, exist among them. Now, as this tendency to variation cannot be clearly traced to any influence of external circumstances, it is commonly distinguished by the term 'spontaneous;' but as there is no effect without a cause, and as the widest differences of this kind present themselves in those races which are most obviously amenable to the influence of external conditions, we seem justified in attributing them to agencies operating unostensibly upon the parents, either previously to their intercourse, or at the time of coition (§ 880), or in the female during the

period of utero-gestation (§ 883). The difference between wild and domesticated animals in regard to *colour* affords a very good illustration of this general fact, for the uniformity among the former is no less remarkable than the want of constancy among the latter; and whilst variety of colour soon gives-place to uniformity, when domesticated races return in any considerable degree towards their primitive state,* it very speedily developes itself in races which are undergoing the converse process.†

945. Now it is by taking advantage of those 'spontaneous' departures from the ordinary type, which present features of value to the breeders of domesticated animals, that *new races* are developed from time to time among these; any strongly-marked peculiarity which thus appears in only a single individual, being usually transmitted to some of its offspring, and being almost certainly perpetuated when *both* parents are distinguished by it, as happens when the products of the first procreation become capable of breeding with each other.‡ – Now there can be no hesitation in admitting, that the tendency to the so-called 'spontaneous' variation prevails in the Human race to a greater degree than in any other; since we find most remarkable diversities in features, complexion, hair, and general conformation, among the offspring of the same parentage; whilst more special modifications of the ordinary type, such as the possession of six fingers on each hand and of six toes on each foot, are of no unfrequent occurrence. Under ordinary circumstances, these modifications tend to disappear as often as they occur; the free intermixture of those members of the race which possess them, with those which depart less from the ordinary type, tending to merge them in the general average. But there can be no reasonable doubt, that if the same kind of segregation were practised among Mankind, which is adopted by the breeders of animals for the purpose of perpetuating a particular variety,—if, for example, the members of a six fingered family were to intermarry exclusively with one another,—any such variety would be permanently established as a new race. Now if it be borne in mind, that the influence of a scanty population, in the early ages of the Human race, by isolating different families from each other, and causing intermarriages among even the nearest relatives, would have been precisely the same with that which is now exercised by the

* This has been especially noticed in the dogs, horses, cattle, sheep, and hogs, introduced by the Spaniards into South America.

† Thus Mr. T. Bell informs us ("British Quadrupeds," 2nd edit., p. 203), that an Australian bitch, or dingo, in the Zoological Gardens, had a litter of puppies, the father of which was also of that breed; both parents had been taken in the wild state; both were of the uniform reddish-brown colour which belongs to the race, and the mother had never bred before; but the young, generated in confinement, and in a half-domesticated state, were all more or less spotted.

‡ See the history of the introduction of the *ancon* breed of sheep, characterized by a peculiar conformation of its limbs, in Massachusetts, given by Col. Hutchinson in the "Phil. Trans." for 1813. A similar account has been more lately given by Prof. Owen (in a Lecture delivered before the Society of Arts, Dec. 10, 1851), respecting the recent introduction of a new breed of merino sheep, distinguished for the long, smooth, straight, and silky character of the wool, and now known as the *Mauchamp* breed. In both instances, the breed originated in the spontaneous appearance of a male lamb possessing the peculiarities in question; from its offspring such a selection was made by the breeder, as enabled him to bring together males and females, both of which were distinguished by them; and in their progeny, the peculiarities uniformly appeared.

breeders of animals, we see one reason why the varieties which *then* arose should have a much greater tendency to self-perpetuation, than those which *now* occasionally present themselves. And when, too, it is borne in mind, that the change in external conditions induced by migration, would thus operate not only upon the parents but upon the offspring, and would have a continual influence in so modifying the constitution of the latter, that the peculiarities thus acquired by them would be transmitted in yet greater intensity to their progeny, there is no real difficulty in accounting, upon the strictest physiological principles, for the widest departures from one common type of conformation, which we encounter in our survey of the different Races of Mankind.*

946. Hence we are led to conclude, that, so far as regards their Anatomical structure, there is no such difference among them as would justify to the Zoologist the assertion of their distinct origin. But further, although the comparison of the structural characters of the Human races does not furnish any positive evidence of their descent from a common stock, it justifies the assertion that even if their stocks *were* originally distinct, there could have been no essential difference between them; the descendants of any one such stock being able to assume the characters of another. This, as already remarked, can be proved by historical evidence in regard to a sufficient number of tribes, to justify the same assertion with respect to others, whose languages, customs, habits of thought, &c. have an affinity strong enough to warrant us in regarding them as descendants of the same stock, whilst their physical conformation is widely different. Each principal geographical area, which is so isolated from others as to render it probable, *à priori*, that its population has extended from one centre,—such as the Continent of Africa, or America,—contains races of very diversified physical characters, whose linguistic affinities make it almost certain that they must have had a common descent; and thus, in whatever mode the types of the principal varieties are selected, they are found to be connected by so gradual a series of intermediate or transitional forms, that it is impossible to draw any such line of demarcation between them, as would be required by a soundly judging Naturalist for the boundary of distinct species.

947. A very important confirmation of this view, is afforded by the essential agreement which exists among the different Races of Men in regard to their Physiological history; the variations which they present not being greater than those which we meet-with between the different individuals of any one race. Thus, we not only find the average duration of life to be the same (making allowance for circumstances which are likely to induce disease) but the various epochs of life,—such as the times of the first and second dentition, the period of puberty, the duration of pregnancy, the intervals of the catamenia, and the time of their final cessation,—present a marked general uniformity, such as does not exist

* For a masterly digest of the analogical evidence furnished by the changes known to have been thus produced among domesticated animals, and of the modifications which particular tribes of Men can be shown to have undergone within the historic period, see Dr. Prichard's "Physical History of Mankind," and his "Natural History of Man;" see also the summary given by the Author in the "Cyclop. of Anat. and Physiol.," vol. iv. pp. 1301-1339.

among similar epochs in the lives of species that are nearly allied but yet unquestionably distinct. Further, the different races of Man are all subject to the same diseases, both sporadic, endemic, and epidemic; the only exceptions being those, in which the constitution of a race has *grown to* a certain set of influences (as that of the Negro to the malaria which generate certain pernicious fevers in the European), producing an hereditary immunity in the race, which is capable of being acquired by individuals of other races, by a process of acclimatization commenced sufficiently early.*—The most important physiological test, however, of specific unity or diversity, is that furnished by the Generative process. It may be considered as a fundamental fact, alike in the Vegetable and in the Animal kingdom (PRINC. OF COMP. PHYS., § 615), that *hybrid* races originating in the sexual connection of individuals of two different *species*, do not tend to self-perpetuation; the hybrids being nearly sterile with each other, although they may propagate with either of their parent-races, in which the hybrid race will soon merge; whilst, on the other hand, if the parents be themselves *varieties* of the same species, the hybrid constitutes but another variety, and its powers of reproduction are rather increased than diminished, so that it may continue to propagate its own race, or may be used for the production of other varieties, almost *ad infinitum*. It appears that, among Plants, hybrids originating between undoubtedly distinct species, sometimes reproduce themselves for two or three generations, but do not continue beyond the fourth. Amongst Animals, the limits of hybridity between parents of distinct species are more narrow, since the hybrid is totally unable to continue its race with one of its own kind;† and although it may propagate with one of its parent-species, the progeny will of course approach in character to the pure breed, and the race will speedily merge into it. In Animals, as among Plants, the mixed offsprings, originating from different races within the limits of the same species, generally *exceed* in vigour, and in the tendency to multiply, the parent-races from which they are produced, so as to gain ground upon the older varieties, and gradually to supersede them. In this manner, by the *crossing* of the breeds of our domesticated animals, many new and superior varieties have been produced. The general principle is, then, that beings of distinct *species*, or descendants

* This view of the immunity of the Negro race from certain forms of Fever which are very fatal to Europeans, is justified, the Author believes, by all the facts known upon the subject. Much may be set down, as he is assured by Dr. Daniell, to the better adaptation of the Negro habits of life to their climate; and Europeans who exercise due caution (especially in regard to the functions of the skin), may preserve an immunity scarcely less complete. Dr. D. himself, having been taken prisoner by one of the Negro tribes at an early age, and having spent two years among them, seems to have been thoroughly acclimatized; and has subsequently passed many years on the most unhealthy parts of the coast, without experiencing any severe attacks of illness, and in the enjoyment of very good general health. It is sometimes maintained that the Negro race possesses such a complete exemption from the Yellow Fever of the United States, as marks its specific difference; such, however, is not constantly the case, since Negroes occasionally suffer from it; and their *comparative* immunity seems fairly attributable to the constitutional peculiarity *acquired* by their African progenitors, and capable of being acquired by Europeans also.

† One or two instances have been stated to occur, in which a Mule has produced offspring from union with a similar animal; but this is certainly the extreme limit, since no one has ever maintained that the race can be continued further than the second generation, without admixture with one of the parent-species.

from stocks originally different, cannot produce a mixed race which shall possess the capability of perpetuating itself, whilst the union of *varieties* has a tendency to produce a race superior in energy and fertility to its parents.—The application of this principle to the Human races, leaves no doubt with respect to their specific unity; for, as is well known, not only do all the races of Men breed freely with each other; but the mixed race is generally superior in physical development, and in tendency to rapid multiplication, to either of the parent-stocks; so that there is much reason to believe that, in many countries, the mixed race between the Aborigines and European colonizers will ultimately become the dominant power in the community. This is especially the case in India, South America, and Polynesia.

948. The question of *Psychical* conformity or difference among the Races of Mankind, is one which has a most direct bearing upon the question of their specific unity or diversity; but it has an importance of its own, even greater than that which it derives from this source. For, as has been recently argued with great justice and power,* the real Unity of Mankind does not lie in the consanguinity of a common descent, but has its basis in the participation of every race in the same moral nature, and in the community of moral rights which hence becomes the privilege of all. "This is a bond which every man feels more and more, the farther he advances in his intellectual and moral culture, and which in this development is continually placed upon higher and higher ground; so much so, that the physical relation arising from a common descent is finally lost-sight-of, in the consciousness of the higher moral obligations." It is in these obligations, that the moral *rights of men* have their foundation; and thus, "while Africans have the hearts and consciences of human beings, it could never be right to treat them as domestic cattle or as wild fowl, if it were ever so abundantly demonstrated that their race was but an improved species of ape, and ours a degenerate kind of god."—The Psychical comparison of the various Races of Mankind, is really, therefore, in a practical point of view, the most important part of the whole investigation; but it has been, nevertheless, the one most imperfectly pursued, until the inquiry was taken-up by Dr. Prichard. The mass of evidence which he has accumulated on this subject, however, leaves no reasonable doubt, that no more "impassable barrier" really exists between the different races with respect to this, than in regard to any of those points of ostensible diversity which have been already considered; the variations in the positive and relative development of their respective psychical powers and tendencies, not being greater, either in kind or degree, than those which present themselves between individuals of our own or of any other race, by some members of which a high intellectual and moral standard has been attained. The tests by which we recognise the claims of the outcast and degraded of our own or of any other 'highly-civilized' community, to a common humanity, are the same as those by which we should estimate the true relation of the Negro, the Bushman, or the Australian, to the cultivated European. If, on the one hand, we admit the influence of want, ignorance, and neglect, in accounting for the debasement of the savages of our own great cities,—and if we witness

* See the "New Quarterly Review," No. xv. p. 131; and an Article by Prof. Agassiz in the "Christian Examiner," Boston (N. E.), 1850.

the same effects occurring under the same conditions among the Bushmen of Southern Africa (§ 958),—we can scarcely hesitate in admitting, that the long-continued operation of the same agencies has had much to do with the psychical as well as the physical deterioration of the Negro, Australian, and other degraded races. So, on the other hand, if we cherish the hope that the former, so far from being irreclaimable, may at least be brought-up to the standard from which they have degenerated, by means adapted to develope their intellectual faculties and to call-forth the higher parts of their moral nature, no adequate reason can be assigned why the same method should not succeed with the latter, if employed with sufficient perseverance. It will be only when the effect of education, intellectual, moral, and religious, shall have been fairly tested by the experience of *many generations*, in conjunction with the influence of a perfect equality in civilization and social position, that we shall be entitled to speak of any essential and constant psychical difference between ourselves and the most degraded beings clothed in human form. All the evidence which we at present possess, leads to the belief, that under a vast diversity in degree and in modes of manifestation, the same intellectual, moral, and religious *capabilities* exist in all the Races of Mankind; so that, whilst we may derive from this conformity a powerful argument for their zoological Unity as a species, we are also directly led to recognize their community of moral nature with ourselves, and to admit them to a participation in our own rights.

949. Most important assistance is afforded in the determination of the real affinities of different Races, by the study of their *Languages*. This, however, is a department of the inquiry so far beyond the limits of Physiological science, that it must be here dismissed with a bare mention of those results, to which the zealous pursuit of it by a large number of philosophic Philologists seems undoubtedly to tend.—There can be no reasonable doubt that, as a general principle, the affinities of races are more surely indicated by their languages, than by their physical features; and the experienced philologist is generally able to discriminate those resemblances, which may have arisen out of the introduction of words or of modes of construction from the one into the other, by conquest, commercial intercourse, or absolute intermixture, from those which are the result of a community of origin. And thus are supplied those means of tracing the past history of races, which are seldom afforded by written records, or even (at least with any degree of certainty) by traditional information. It is to be borne in mind, that the affinities of languages are indicated, not merely by verbal resemblance, but by the similarity of their modes of grammatical construction, or the methods by which the relation between different words that constitute sentences is indicated. The most positive evidence is of course afforded, when a conformity exists both in the *vocabularies* and in the *modes of construction* of two languages; but it frequently happens that although the conformity exists in regard to one of these alone, yet the evidence which it affords is perfectly satisfactory. Thus, there are many cases in which the vocabularies are so continually undergoing important changes (the want of written records not permitting them to acquire more than a traditional permanence), that their divergence becomes so great, even in the course of a few generations, as to prevent tribes which are by no means remotely

descended from a common ancestry, from understanding one another; whilst yet the system of grammatical construction, which depends more upon the grade of mental development and upon habits of thought, exhibits a remarkable permanence. Such appears to be true of the entire group of American languages; which seem, as a whole, to be legitimately referable to a common stock, notwithstanding their complete verbal diversity. On the other hand, when two languages or groups of languages differ greatly in construction, but present that kind of verbal correspondence on which the philologist feels justified in placing most reliance (namely, an essential conformity in those 'primary words' which serve to represent the universal ideas of a people in the most simple state of existence), that correspondence may be held to indicate a community of origin, if it can be proved that it has not been the result of intercourse between the two families of nations subsequently to their first divergence, and if it seems probable on other grounds that their separation took place at a period when as yet the grammatical development of both languages was in its infancy. Such appears to have been the case with certain of those groups of languages, whose distinctness can be traced back historically for the longest period.—It is evident, then, that Philological inquiry must be looked-to as one of the chief means of determining the question of radiation from a *single* centre or from *multiple* centres; and it is a remarkable fact, that the linguistic affinity and the conformity in physical characters frequently stand in a sort of complemental relation to each other, each being the strongest where the other is weakest; so that, by one or other of these links of connection, a close relationship is indicated between all those families of nations, under which the several races appear to be most naturally grouped.

2. *General Survey of the Principal Varieties of the Human Species.*

950. The distribution of the Races of Mankind under five primary varieties, according to their respective types of cranial conformation, as first proposed by Blumenbach, is still so commonly received, notwithstanding the distinct proof which has been given of the fallacious nature of its basis, that it will be desirable to explain his terms, and at the same time to show how far the information subsequently acquired has tended to modify his arrangement.—The first of these varieties, which is considered to be distinguished by the possession of the *oval* or *elliptical* type of cranial conformation, was designated *Caucasian* by Blumenbach, on two grounds; first, because he considered the Caucasian people (of whom the Georgians and Circassians are the best-known examples), as presenting its physical characters in the greatest perfection, and second, because it was supposed that the Caucasian range of mountains might be regarded as the centre or focus of the races belonging to it. Neither of these ideas, however, is correct: for whilst the oval form of cranium is presented with fully as great beauty and symmetry by the Greeks, it seems now to be almost certainly determinable by the evidence of language, that the Georgian and Circassian nations are really of Mongolian origin, and consequently have no direct relation of affinity with the other nations usually ranked as belonging to this variety; and the evidence of history and tradition, so far from pointing to the Caucasian range as the

original centre of radiation of the race, accords with that of language in assigning its locality much nearer to Central Asia. It would be most desirable, therefore, that some other designation should be substituted for that given by Blumenbach; were it not that the present state of our knowledge requires the entire abandonment of his doctrine, that the races agreeing in this type of conformation are mutually connected by community of descent. For, even within the limits of Europe, we find at least two nations,—the Turks, and the Magyars or true Hungarians,—whose crania are characteristically oval, and which are yet undoubtedly of Mongolian origin; and although some allowance must be made, in regard to the change which has taken place among the former, for the influence of intermixture with other races, yet there is no reason to believe that any such influence has operated among the Magyars, whose blood seems to have been transmitted with remarkable purity from the time when they settled in Hungary about ten centuries since. In Asia, we find this type presented not merely by the Persian and other Indo-European races, but also by the Syro-Arabian, and by the larger proportion of the inhabitants of Hindostan; yet the Syro-Arabian races are more nearly related to the African stock (§ 952), than to that from which most of the present inhabitants of Europe have sprung; and there is good reason to believe that the great mass of the existing inhabitants of India, are of Mongolian descent (§ 954). It will be necessary, therefore, to consider the nations which present the so-called Caucasian type of cranial conformation, under several distinct heads. No uniformity exists among them in regard to *colour*; for this character presents every intermediate gradation between the fair and florid tint, with light red or auburn hair, of the Northern European, to the dusky or even black hue of the races bordering-on or lying-between the Tropics. The hair is generally long and flexible, with a tendency to curl; but considerable variety presents itself with regard to this particular. The conformation of the features approaches more or less closely to that which we are accustomed to regard as the type of beauty.

951. The first place, in a more natural distribution of the Human Races, must undoubtedly be given to that which is designated by Dr. Prichard as the *Arian*, and which is often termed the *Indo-European*; including the collective body of European nations, with the Persians,* Affghans, and certain other nations of the south-western portion of the Asiatic continent,† near to which their original focus appears to have been. The great bond of connection between these nations, lies in their languages; which, in spite of great diversities, present a certain com-

* The modern Persians are a very mixed race, in which Turkish and Arab elements largely participate. The most perfect representatives of the original stock (whose purity of descent seems to have been maintained, from the time of their original migration into their present locality, by the physical obstacles which have cut them off from intercourse with their nearest neighbours) are believed to be the Kafirs of Kafiristan, a fair-skinned light-haired race inhabiting the impracticable mountain-country on the watershed between the Oxus and the north-western sources of the Indus. The Tajiks of Bokhara also keep up the ancient lineage and language, although their country is ruled by people of Turkish descent.

† The population of Hindostan has been commonly accounted as belonging to this division; but the more intimate the knowledge attained of its character and languages, the more does it lead to the conclusion that the great mass of this population is really of Mongolian descent (§ 954).

munity of character that is recognized by every philologist. For they are obviously all formed upon the same base with the ancient Sanskrit, if not upon the Sanskrit itself, and they are united alike by community in many of the most important 'primary words,' and by general similarity in grammatical construction. The existing Lettish or Lithuanian dialect presents a very near approach to the original type; and the Old Prussian, a dialect spoken as late as the sixteenth century, had a still closer alliance to the ancient Zend or Median, which seems to have been a very early derivation from the Sanskrit, and which is the basis of the language now spoken in Persia. The family which is most dissimilar to the rest (the typical Celt contrasting remarkably with the types of the Germanic group, both in physical conformation and in psychical characters,) is that which is formed by the Celtic nations; but these are undoubtedly, like the others, of Eastern origin, as was first shown by Dr. Prichard,* though they appear to have detached themselves from the common stock at an earlier period in the development of its language.—But there is evidence that, notwithstanding the mutual affinities of the Indo-Germanic languages, every one of them has been modified by the introduction of extraneous elements: thus, in those of Western Europe, there is a considerable admixture of Celtic; whilst in others, there are traces of more barbaric tongues. In fact, there can be little doubt that Europe had an indigenous population, before the immigration of the Indo-German or even of the Celtic tribes; and of this population it seems most probable that the Lapps and Finns of Scandinavia, and the Euskarians (or Basques) of the Biscayan provinces, are but the remnant. The former of these tribes, which is undoubtedly of Mongolian origin, once extended much further south than at present; and with regard to the latter, whose nearest linguistic affinities are also with the tongues of High Asia, there is ample historical proof that they had formerly a very extensive distribution through Southern Europe. It would not seem improbable, then, that the advance of the Indo-European tribes from the south-east corner into central Europe, separated that portion of the aboriginal (Mongolian) population which they did not absorb or destroy, into two great divisions, of which one was gradually pressed northward and eastward, so as to be restricted to Finland and Lapland; and the other southward and westward, so as to be confined at the earliest historic period to a part of the peninsula of Spain and the South of France, gradually to be driven before the successive irruptions of the Celts, Romans, Arabians, and other nations, until their scanty remnant found an enduring refuge in the fastnesses of the Pyrenees.† —The Indo-Germanic race is unquestionably that which has exercised the greatest influence on the civilization of the Old World; and it seems indubitably destined to acquire a similar influence in those newly-found lands, which have been discovered by its enterprise. With scarcely an exception, as Dr. Latham has justly remarked, the nations belonging to it present an *encroaching* frontier; there

* "On the Eastern Origin of the Celtic Nations," 1831.

† This view, which was suggested by the Author in the "Brit. and For. Med. Rev.," Oct. 1847, without the knowledge that it had been elsewhere propounded, has been put-forth with considerable confidence by Dr. Latham, ("Varieties of Man," 1850), as having originated with Arndt and been adopted by Rask, distinguished Scandinavian ethnologists.

being no instance of its permanent displacement by any other race, save in the case of the Arab dominion in Spain, which has long since ceased; in that of the Turkish dominion in Turkey and Asia Minor, which is evidently destined to expire at no distant period, being upheld for merely political purposes by extraneous influence; and in that of the Magyars in Hungary, who only maintain their ground through their complete assimilation to the Indo-Germanic character. It is a remarkable fact, that in most cases in which this race extends itself into countries previously tenanted by people of an entirely different type, the latter progressively decline and at last disappear before it, provided the climate be such as enables it to maintain a vigorous existence; this is pre-eminently the case in North and South America, in Australia, in New Zealand, and in many of the smaller Polynesian islands. And where the climate is less favourable to the perpetuation of the race in its purity, an intermixture with the native blood frequently gives origin to a mixed race, which possesses the developed intellect of the one, and the climatic adaptiveness of the other, and which appears likely ultimately to take the place of both.

952. The *Syro-Arabian* or *Semitic* nations agree with the preceding in general physical characters, but differ entirely in the structure of their language, and for the most part in vocabulary also, though recent researches seem to indicate that certain *roots* of the Semitic and Indo-Germanic languages have a decided affinity. It seems quite certain, however, that the linguistic affinities of the Semitic nations are rather with the *African* than with the Indo-European races; and so strong is the link of connection thus established, that by Dr. Latham they are ranked with the former under the general designation *Atlantidæ*,* whilst Mr. Norris, whose authority upon all such subjects is deservedly great, is strongly disposed (as he has himself informed the Author) to consider them an *essentially African* people.—The original seat of this race, however, is commonly reputed to have been that region of Asia which is intermediate between the countries of the Indo-European and of the Egyptian races; having as its centre the region watered by the great rivers of Mesopotamia. Several of the nations primarily constituting this group have become extinct, or nearly so; and the *Arabs*, which originally formed but one subdivision of it, have now become the dominant race, not only throughout the ancient domain of the Syro-Arabian nations, but also in Northern Africa. In the opinion of Baron Larrey, who had ample opportunities for observation, the skulls of the Arabian race furnish, at present, the most complete type of the human head; and he considered the remainder of the physical frame as equally distinguished by its superiority to that of other races of men. The different tribes of Arabs present very great diversities of colour, which are generally found to coincide with variations in climate. Thus the Shegya Arabs, and others living on the low countries bordering on the Nile, are of a dark-brown or even black hue; but even when quite jetty, they are distinguished from the Negro races by the brightness of their complexions, by the length and straightness of their hair, and by the regularity of their features. The same may be said of the wandering Arabs of Northern Africa; but the influence of

* See his "Varieties of Man," 1850, p. 469.

climate and circumstances is still more strongly marked in some of the tribes long settled in that region, whose descent may be traced to a distinct branch of the Syro-Arabian stock, namely, the *Berber*, to which belong the Kabyles of Algiers and Tunis, the Tuaryks of Sahara, and the Guanches or ancient population of the Canary Isles. Amongst these tribes, whose affinity is indisputably traceable through their very remarkable language, every gradation may be seen, from the intense blackness of the Negro skin, to the more swarthy hue of the inhabitants of the South of Europe. It is remarkable that some of the Tuaryk inhabitants of particular Oases in the great desert, who are almost as insulated from communication with other races as are the inhabitants of islands in a wide ocean, have hair and features that approach those of the Negroes; although they speak the Berber language with such purity, as to forbid the idea of the introduction of these characters by an intermixture of races. The *Jews*, who are the only remnants now existing of the once-powerful Phœnician tribe, and who are now dispersed through nearly every country on the face of the earth, present a similar diversity; having gradually assimilated in physical characters to the nations among which they have so long resided (§ 934).

953. The second primary division of the Human family, according to the arrangement of Blumenbach, is that commonly termed *Mongolian*. The real Mongols, however, constitute but a single and not very considerable member of the group of nations associated under this designation; which is, therefore, by no means an appropriate one. The original seat of these races appears to have been the great central elevated plain of Asia, in which all the great rivers of that continent have their sources, whatever may be their subsequent direction. Taken as a whole, this division is characterized by the pyramidal form of the skull, whose antero-posterior diameter scarcely exceeds the parietal, and by the broad flat face and prominent cheek bones; by the flattening of the nose, which is neither arched nor aquiline; by the eyes being drawn upwards at their outer angle; by the xanthous or olive complexion, which sometimes becomes fair, but frequently swarthy; by the scantiness and straightness of the hair, and deficiency of beard; and by lowness of stature. These characters, however, are exhibited in a prominent degree only in the more typical members of the group, especially those inhabiting Northern and Central Asia, and may become so greatly modified, as to cease altogether to be recognizable. Such a modification has been remarkably effected in the case of a part of the *Turkish* people, now so extensively distributed. All the most learned writers on Asiatic history are agreed in opinion, that the Turkish races are of one common stock; although at present they vary in physical characters, to such a degree that, in some, the original type has been altogether changed. Those which still inhabit the ancient abodes of the race, and preserve their pastoral nomadic life, present the physiognomy and general characteristics which appear to have belonged to the original Turkomans, and these are decidedly referable to the so-called Mongolian type. Before the Mahommedan era, however, the Western Turks or Osmanlis had adopted more settled habits, and had made considerable progress in civilization, and their adoption of the religion of Islam incited them to still wider extension, and developed that spirit of conquest, which, during the middle ages

displayed itself with such remarkable vigour. The branches of the race, which, from their long settlement in Europe, have made the greatest progress in civilization, now exhibit in all essential particulars the physical characters of the European model, and these are particularly apparent in the conformation of the skull. Another marked departure from the ordinary Mongolian type, is presented by the Hyperborean tribes inhabiting the borders of the Icy Sea, these have for the most part a pyramidal skull, but their complexion is swarthy and their growth is peculiarly stunted; and they form the link that connects the ordinary Mongolidæ with the Lapps and Finns of Europe on one side, and with the Esquimaux of North America on the other. The Ugrian division, which migrated towards the north-west at a very early period, planted a colony in Europe, which still tenants the northern Baltic countries, forming the races of *Finns* and *Lapps*. In the time of Tacitus, the Finns were as savage as the Lapps; but the former, during the succeeding ages, became so far civilized, as to exchange a nomadic life for one of agricultural pursuits, and have gradually assimilated with the surrounding people, whilst the Lapps, like the Siberian tribes of the same race, have ever since continued to be barbarous nomades, and have undergone no elevation in physical characters. The same division gave origin to the *Magyars* or Hungarians, a warlike and energetic people, unlike their kindred in the North; in whom a long abode in the centre of Europe has, in like manner, developed the more elevated characters, physical and mental, of the European nations.

954. The nations inhabiting the South-eastern and Southern portions of Asia, also, appear to have had their origin in the Mongolian or Central-Asiatic stock; although their features and form of skull by no means exhibit its characteristic marks, but present such departures from it, as are elsewhere observable in races that are making advances in civilization. The conformity to the Mongolian type is most decidedly shown by the nations (collectively termed *Seriform* by Dr. Latham), which inhabit China, Thibet, the Indo-Chinese peninsula, and the base of the Himalayan range; these are associated by certain linguistic peculiarities which distinguish them from all other races; that primitive condition of human speech, in which there is a total absence of inflections indicative of the relation of the principal words to one another, being apparently preserved with less change in the tongues of these people, than in those of any other. The Chinese may be physically characterized as Mongolians softened-down; and in passing from China towards India, through the Burmese empire, there is so gradual a transition towards the ordinary Hindoo type, that no definite line of demarcation can be anywhere drawn.—The inhabitants of the great peninsula of Hindostan have been commonly ranked (as already remarked) under the Caucasian race, both on account of their physical conformity to that type, and also because it has been considered that the basis of their languages is Sanskritic. It is certain, however, that this conclusion is incorrect with regard to a very large proportion of the existing population of India; and there is strong reason to believe that no part of it bears any real relation of affinity to the Indo-European group of nations, except such as may be derived from a slight intermixture. Thus, the *Tamulian*, which is the dominant language of *Southern* India, is undoubtedly not Sans-

kritic in its origin (although containing an infusion of Sanskritic words), but more closely approximates to the Seriform type; and many of the hill-tribes, in different parts of India, speak peculiar dialects, which, though mutually unintelligible, appear referable to the same stock. Now it is among this portion of the population of India, that the greatest departure presents itself from the Caucasian type of cranial formation, and the closest conformity to the Mongolian, the cheek-bones being more prominent, the hair coarse, scanty, and straight, and the nose flattened; sometimes, also, the lips are very thick, and the jaws project, showing an approximation to the prognathous type. Now in the opinion of Dr Latham and Mr. Norris, the various dialects of *Northern* India (of which the *Hindostani* is the most extensively spoken) are to be regarded as belonging, in virtue of their fundamental nature, to the same group with those of High Asia, notwithstanding the large infusion of Sanskritic words which they contain; this infusion having been introduced at an early period by an invading branch of the Arian stock, of whose advent there is historical evidence, and whose descendants the ordinary Hindoo population have been erroneously supposed to be. According to this view, then, the influence of the Arian invasion upon the language and population of Northern India, was very much akin to that of the Norman invasion upon those of England; the number of individuals of the invading race being so small in proportion to that of the indigenous population, as to be speedily merged in it, not, however, without contributing to an elevation of its physical characters; and a large number of new words having been in like manner introduced, without any essential change in the type of the original language. And thus the only distinct traces of the Arian stock are to be found in the Brahminical caste, which preserves (though with great corruption) the original Brahminical religion, and which keeps-up the Sanskrit as its classical language: it is certain, however, that this race is far from being of pure descent, having intermingled to a considerable extent with the ordinary Hindoo population. There is but little to remind us of the Mongolian type in the countenances of the Hindoos, which are often remarkable for a symmetrical beauty that only wants a more intellectual expression to render them extremely striking; some traces of it, however, may perhaps be found in the rather prominent zygomatic arches which are common amongst them; but the cranial portion of the skull presents no approach to the pyramidal type, being often very regularly elliptical. There is a remarkable difference in the colour of the different Hindoo tribes, some being nearly as dark as Negroes, others more of a copper colour, and others but little darker than the inhabitants of Southern Europe.

955. According to the usual mode of dividing the Human family, the *Ethiopian* or *Negro* stock is made to include all the nations of Africa, to the southward of the Atlas range. But, on the one hand, the Hottentots and Bushmen of the southern extremity constitute a group which is strongly distinguished by physical characters from the rest of the African nations; so, again, the region north of the Great Desert is mostly occupied by *Semitic* tribes (§ 952); the scattered population of the Great Desert itself is far from being Negro in many of its features; the valley of the Nile, at least in its middle and lower portions, including Egypt, Nubia, and even Abyssinia, is inhabited by a group of nations which

may be designated as Nilotic, and which presents a series of gradational transitions between the Negroes and Kaffres and the Semitic races; a large portion of the area south of the Equator is occupied by the Kaffre tribes and their allies, which cannot be truly designated as Negroes: so that the true Negro area is limited to the western portion of the African continent, including the alluvial valleys of the Senegal, the Gambia, and the Niger, with a narrow strip of central Africa, passing eastwards to the alluvial regions of the Upper Nile. Even within this area, the true Negro type of conformation, such as we see in the races which inhabit the low countries near the Slave Coast,—consisting in the combination of the prognathous form of skull with receding forehead and depressed nose, thick lips, black woolly hair, jet-black unctuous skin, and crooked legs, is by no means universally prevalent; for many of the nations which inhabit it, must be ranked as *sub-typical* Negroes, and from these the gradation in physical characters is by no means abrupt, to those African nations which possess, in a considerable degree, the attributes which we are accustomed to exclude altogether from our idea of the African race. Thus, the race of Jolofs near the Senegal, and the Guber in the interior of Sudan, have woolly hair and deep-black complexions, but fine forms and regular features of a European cast; and nearly the same may be said of the darkest of the Kaffres of Southern Africa. The Bechuana Kaffres present a still nearer approach to the European type; the complexion being of a light-brown, the hair often not woolly but merely curled, or even in long flowing ringlets, and the figure and features having much of the European character.—There is no group, in fact, which presents a more constant correspondence between external conditions and physical conformation, than that composed of the African nations. As we find the complexion becoming gradually darker, in passing from Northern to Southern Europe, thence to North Africa, thence to the borders of the Great Desert, and thence to the intertropical region where alone the dullest black is to be met with,—so do we find, on passing southwards from this, that the hue becomes gradually lighter in proportion as we proceed further from the equator, until we meet with races of comparatively fair complexions among the nations of Southern Africa. Even in the intertropical region, high elevations of the surface have the same effect as we have seen them to produce elsewhere, in lightening the complexion. Thus the high parts of Senegambia, where the temperature is moderate and even cool at times, are inhabited by Fulahs of a light copper colour, whilst the nations inhabiting the lower regions around them are of true Negro blackness; and nearly on the same parallel, but at the opposite side of Africa, are the high plains of Enarea and Kaffa, of which the inhabitants are said to be fairer than the natives of Southern Europe.

956. The languages of the Negro nations, so far as they are known, appear to belong to one group; for although there is a considerable diversity in their vocabularies (arising in great part from the want of written records which would give fixity to their tongues), yet they seem to present the same grade of development and the same grammatical forms, and various proofs of their affinity with the Semitic languages have been developed, these being afforded by similarity alike of roots and of grammatical construction. The Semitic affinity of the Negro

nations is further indicated in a very remarkable manner, by the existence of a variety of superstitions and usages among the Negroes of the Western coast, closely resembling those which prevail also among the Nilotic races whose Semitic relations are most clear, as well as among branches of the Semitic stock itself; and thus we seem to have adequate proof of the absence of any definite line of demarcation, in regard either to *physiological* or to *linguistic* characters, between the Negro race, and one of those which has been hitherto considered to rank among the most elevated forms of the Caucasian variety.—Nor is there anything in the *psychical* character of the Negro, which gives us a right to separate him from other races of Mankind. It is true that those races which have the Negro character in an exaggerated degree, are uniformly in the lowest stage of society, being either ferocious savages, or stupid, sensual, and indolent; such are most of the tribes along the Slave Coast. But, on the other hand, there are many Negro States, the inhabitants of which have attained a considerable degree of improvement in their social condition; such are the Ashanti, the Sulima, and the Dahomans of Western Africa, also the Guber of Central Sudan, among which a considerable degree of civilization has long existed; the physical characters of all these nations deviate considerably from the strongly-marked or exaggerated type of the Negro; and the last are perhaps the finest race of genuine Negroes on the whole continent, and present in their language the most distinct traces of original relationship to the Syro-Arabian nations. The highest civilization, and the greatest improvement in physical characters, are to be found in those African nations which have adopted the Mahommedan religion; this was introduced, three or four centuries since, into the eastern portion of Central Africa; and it appears that the same people, which were then existing in the savage condition still exhibited by the pagan nations further south, have now adopted many of the arts and institutions of civilized society, subjecting themselves to governments, practising agriculture, and dwelling in towns of considerable extent, many of which contain 10,000, and some even 30,000 inhabitants; a circumstance which implies a considerable advancement in industry, and in the resources of subsistence. This last fact affords most striking evidence of the *improvability* of the Negro races; and, taken in connection with the many instances that have presented themselves, of the advance of individuals, under favourable circumstances, to at least the average degree of mental development among the European nations, it affords clear proof that the line of demarcation, which has been supposed to separate them intellectually and morally from the races that have attained the greatest elevation, has no more *real* existence than that which has been supposed to be justified by a difference in physical characters, and of which the fallacy has been previously demonstrated.

957. The southern portion of the African continent is inhabited by a group of nations, which (as already mentioned) recede more or less decidedly from the Negro type in physical characters, and which seem connected together by essential community of language, as branches of the stock of which the *Kaffres* may be considered the stem. In this warlike nomadic people, which inhabit the eastern parts of South Africa, to the northward of the Hottentot country, so great a departure from

the ordinary Negro type presents itself, that many travellers have assigned to them a different origin. The degree of this departure, however, varies greatly in the different Kaffre tribes; for whilst some of them are black, woolly-headed, and decidedly prognathous, so as obviously to approach the modified Negroes of Congo in general aspect, others recede considerably from the typical prognathous races, both in complexion, features, and form of head, presenting a light-brown colour, a high forehead, a prominent nose, and a tall, robust, well shaped figure. The thick lips and black frizzled hair, however, are generally retained; though the hair is sometimes of a reddish colour, and becomes flowing, and the features may present a European cast. But even among the tribes which depart most widely from the Negro type, individuals are found who present a return to it, and it is interesting to remark, that the people of Delagoa Bay, though of the Kaffre race (as indicated by their language), having been degraded by subjugation, approach the people of the Guinea Coast in their physical characters. In fact, between the most elevated Kaffre and the most degraded Negro, every possible gradation of physical and psychical characters is presented to us, as we pass northwards and westwards from Kaffraria towards the Guinea Coast, and we meet with a similar transition, although not carried to so great an extent, as we pass up the eastern coast. The languages of the Kaffres and other allied tribes are distinguished by a set of remarkable characters, which have been considered as isolating them from other African tongues. According to Dr. Latham, however, these peculiarities are not so far without precedent elsewhere, as to establish the very decided line of demarcation which some have attempted to draw; and may be regarded, in fact, as resulting from the fuller development of tendencies which manifest themselves in other African languages.

958. The *Hottentot* race differs from all other South African nations, both in language and in physical conformation. Its language cannot be shown to possess distinct affinities with any other stock,* but in bodily structure there is a remarkable admixture of the characters of the Mongolian with those of the Negro. Thus the face presents the very wide and high cheek-bones, with the oblique eyes and flat nose, of the Northern Asiatics; at the same time that, in the somewhat prominent muzzle and thick lips, it resembles the countenance of the Negro. The complexion is of a tawny buff or fawn colour, like the black of the Negroes diluted with the olive of the Mongols. The hair is woolly, like that of the Negroes, but it grows in small tufts scattered over the surface of the scalp (like a scrubbing-brush), instead of covering it uniformly; thus resembling in its comparative scantiness that of the

* It is considered by some, that the Hottentot language is a degraded Kaffre, as the Bushman language is a degraded Hottentot; but the Author is informed by Mr Norris, that he sees no valid ground for this assumption, the affinities of the Hottentot language being rather, in his opinion, with the languages of High Asia, although the connecting links are extremely slight. Such as they are, however, they tend to confirm an idea suggested to the Author, some years since, by the marked reproduction of so many Mongolian characters in the Hottentot race,—that it is the remnant of a migration from Asia, earlier than that in which the great bulk of the African nations have their origin; and that it has been driven down to the remotest corner of the continent, just as the aboriginal (Mongolian) population of south western Europe seems to have been driven back by the Indo European immigration (§ 951).

Northern Asiatics. It is most interesting to observe this remarkab resemblance in physical characters, between the Hottentots and th Mongolian races, in connection with the similarity that exists betwe the circumstances under which they respectively live; and it is not little curious that the Hottentot, as the Mongol, should be distinguishe by the extraordinary acuteness of his vision (§ 775). No two countri can be more similar, than the vast steppes of Central Asia, and th karroos of Southern Africa; and the proper inhabitants of each ar nomadic races, wandering through deserts remarkable for the wid expansion of their surface, their scanty herbage, and the dryness of the atmosphere, and feeding upon the milk and flesh of their horses an cattle. Of the original pastoral Hottentots, however, comparativel few now remain. A large proportion of them have been graduall driven, by the encroachments of the Kaffres and of European colonist and by internal wars with each other, to seek refuge among the ina cessible rocks and deserts of the interior; and have thus been convert from a mild, unenterprising race of shepherds, into wandering hordes o fierce, suspicious, and vindictive savages, treated as wild beasts by the fellow-men, until they become really assimilated to wild beasts in the habits and dispositions. Hence have arisen the tribes of *Bushmen* o *Bosjesmen*, which are generally regarded as presenting the most degrade and miserable condition of which the human race is capable, and hav been supposed (but erroneously) to present resemblances in physic characters to the higher Quadrumana. This transformation has take place, under the observation of eye-witnesses, in the Koranas, a tribe o Hottentots well known to have been previously the most advanced in a the improvements which belong to pastoral life; for having been plu dered by their neighbours, and driven out into the wilderness to subsi upon wild fruits, they have adopted the habits of the Bushmen, an have become assimilated in every essential particular to that miserabl tribe.—It appears, however, from the inquiries of Dr. Andrew Smit that this process of degradation has been in operation quite indepe dently of external agencies; nearly all the South African tribes wh have made any advances in civilization, being surrounded by mo barbarous hordes, whose abodes are in the wildernesses of mountains an forests, and who constantly recruit their numbers by such fugitives a crime and destitution may have driven from their own more hone and more thriving communities; and these people vary their mode o speech designedly, and even adopt new words, in order to make the meaning unintelligible to all but the members of their own associatio This has its complete parallel in the very midst of our own or an other highly-civilized community; all our large towns containing spo nearly as inaccessible to those unacquainted with them, as are the rud caves or clefts of hills, or the burrows scooped-out of the level karro in which the wretched Bushman lies in wait for his prey; and the being tenanted by a people that have been well characterized as *l classes dangereuses*, which, as often as the arm of the law is paralyz issue-forth from the unknown deserts within which they lurk, and riv in their fierce indulgence of the most degrading passions, and in the excesses of wanton cruelty, the most terrible exhibitions of barbari inhumanity. Such outcasts, in all nations, purposely adopt, like th

Bushmen, a 'flash' language; and in their general character and usages, there is a most striking parallel.*

959. The *American* nations, taken collectively, form a group which appears to have existed as a separate family of nations from a very early period in the world's history. They do not form, however, so distinct a variety, in regard to physical characters, as some anatomists have endeavoured to prove; for, although certain peculiarities have been stated to exist in the skulls of the aboriginal Americans, yet it is found on a more extensive examination, that these peculiarities are very limited in their extent,—the several nations spread over this vast continent differing from each other in physical peculiarities, as much as they do from those of the Old World, so that no typical form can be made-out among them. In regard to complexion, again, it may be remarked, that although the native Americans have been commonly characterized as "red men," they are by no means invariably of a red or coppery hue, some being as fair as many European nations, others being yellow or brown, and others nearly, if not quite, as black as the Negroes of Africa, whilst, on the other hand, there are tribes equally red, and perhaps more deserving that epithet, in Africa and Polynesia. Our ordinary notion of the American races, having been chiefly founded upon the characters of those tribes of 'Indians' with whom European settlers first came into contact, proves to be no more applicable to the inhabitants of the Continent generally, than are the characters of the Negro to the population of Africa as a whole (§ 955).—In spite of all this diversity of conformation, it is believed that the structure of their languages affords a decided and clearly-marked evidence of relationship between them (§ 949). Notwithstanding their diversities in mode of life, too, there are peculiarities of mental character, as well as a number of ideas and customs derived from tradition, which seem to be common to them all; and which for the most part indicate a former elevation in the scale of civilization, that has left its traces among them even in their present depressed condition, and still distinguishes them from the sensual, volatile, and almost animalized savages, that are to be met-with in many parts of the Old Continent.—The Esquimaux have been regarded as constituting an exception to all general accounts of the physical characters of the American nations; for in the configuration of their skulls, as also in their complexion and general physiognomy, they conform to the Mongolian type, even presenting it in an exaggerated degree; whilst their wide extension along the whole northern coast of America, through the Aleutian Islands, and even to the Continent of Asia, certainly lends weight to the idea that they derive their origin from the Northern Asiatic stock. But the increased acquaintance which has been recently gained with the tribes that people the north-eastern portion of the American Continent, has clearly shown that no physical separation can be established between the Esquimaux and the Indian Proper; the one form graduating so insensibly into the other as to make the distinction between the two groups as difficult, as on the western side it is easy. Hence the existence of the Esquimaux population in this situation, affords a complete link of transition between the Asiatic and the American nations,

* See "London Labour and the London Poor," p. 2.

in the precise region in which the geographical relations of the two continents would lead us to expect it.

960. It now remains for us to notice the *Oceanic* races, which inhabit the vast series of islands scattered through the great ocean that stretches from Madagascar to Easter Island. There is no part of the world which affords a greater variety of local conditions than this, or which more evidently exhibits the effects of physical agencies on the organization of the human body. Moreover, it affords a case for the recognition of affinities by means of language, that possesses unusual stability; since the insulated position of the various tribes that people the remote spots of this extensive tract, prevents them from exercising that influence upon each other's forms of speech, which is to be observed in the case of nations united by local proximity or by frequent intercourse. Tried by this test, it is found that the different groups of people inhabiting the greater part of these insular regions, although so widely scattered and so diverse in physical characters, are more nearly connected together than most of the families of men occupying continuous tracts of land on the great continents of the globe.—The inhabitants of Oceania seem divisible into two principal groups, which are probably to be regarded as having constituted distinct races from a very early period; these are the Malayo-Polynesian race, and the Negritos or Pelagian Negroes.

961. The *Malayo-Polynesian* group is by far the more extensive of the two; and comprehends the inhabitants of the greater part of the Indian and Polynesian Archipelagoes, with the peninsula of Malacca (which is the centre of the Malays proper), and perhaps the inhabitants of Madagascar. These are all closely united by affinities of language. The proper Malays bear a strong general resemblance to the Mongolian races, and this resemblance is shared, in a greater or less degree, by most of the inhabitants of the Indian Archipelago. They are of a darker complexion, as might be expected from their proximity to the equator; but in this complexion, yellow is still a large ingredient. The Polynesian branch of the group presents a much wider diversity; and if it were not for the community of language, it might be thought to consist of several races, as distinct from each other as from the Malayan branch. Thus the Tahitians and Marquesans are tall and well-made; their figures combine grace and vigour; their skulls are usually remarkably symmetrical, and their physiognomy presents much of the European cast, with a very slight admixture of the features of the Negro. The complexion, especially in the females of the higher classes, who are sheltered from the wind and sun, is of a clear olive or brunette, such as is common among the natives of Central and Southern Europe; and the hair, though generally black, is sometimes brown or auburn, or even red or flaxen. Among other tribes, as the New Zealanders, and the Tonga and Friendly Islanders, there are greater diversities of conformation and hue, some being finely proportioned and vigorous, others comparatively small and feeble, some being of a copper-brown colour, others nearly black, others olive, and others almost white. In fact, if we once admit a strongly-marked difference in complexion, features, hair, and general configuration, as establishing a claim to original distinctness of origin, we must admit the application of this hypothesis to almost every group of islands in the Pacific;—an idea, of which the essential community of language seems to

afford a sufficient refutation. Among the inhabitants of Madagascar, too, all of which speak dialects of the same language, some bear a strong resemblance to the Malayan type, whilst others present approaches to that of the Negro.

962. The *Negrito* or *Pelagian-Negro* races must be regarded as a group altogether distinct from the preceding, having a marked diversity of language, and presenting, more decidedly than any of the Malayo-Polynesians, the characters of the Negro type. They form the predominating population of New Britain, New Ireland, the Louisiade and Solomon Isles, of several of the New Hebrides, and of New Caledonia; and they seem to extend westwards into the mountainous interior of the Malayan Peninsula, and into the Andaman Islands in the Bay of Bengal. The Tasmanians, or aborigines of Van Dieman's Land, which are now almost completely exterminated, undoubtedly belonged to this group. Very little is known of them, except through the reports of the people of Malayo-Polynesian race inhabiting the same islands; but it appears that, generally speaking, they have a very inferior physical development, and lead a savage and degraded life. There is considerable diversity of physical characters among them; some approximating closely in hair, complexion, and features, to the Guinea Coast Negroes; whilst others are of yellower tint, straight hair, and better general development. The *Papuans*, who inhabit the northern coast of New Guinea and some adjacent islands, and who are remarkable for their large bushy masses of half woolly hair, have been supposed to constitute a distinct race; but there is little doubt that they are of hybrid descent, between the Malays and the Pelagian Negroes.—To this group we are probably to refer the *Alfourous*, or *Alforian* race, which are considered by some to be the earliest inhabitants of the greater part of the Malayan Archipelago, and to have been supplanted by the more powerful people of the preceding races, who have either extirpated them altogether, or have driven them from the coasts into the mountainous and desert parts of the interior. They are yet to be found in the central parts of the Moluccas and Philippines; and they seem to occupy most of the interior and southern portion of New Guinea, where they are termed Endamenes. They are of very dark complexion; but their hair, though black and thick, is lank. They have a peculiarly repulsive physiognomy; the nose is flattened, so as to give the nostrils an almost transverse position; the cheek bones project; the eyes are large, the teeth prominent, the lips thick, and the mouth wide. The limbs are long, slender, and misshapen. From the close resemblance in physical characters between the Endamenes of New Guinea and the aborigines of New Holland, and from the proximity between the adjacent coasts of these two islands, it may be surmised that the latter belong to the Alforian race; but too little is known of the language of either, to give this inference a sufficient stability. In the degradation of their condition and manner of life, the savages of New Holland fully equal the Bushmen of South Africa; and it is scarcely possible to imagine human beings, existing in a condition more nearly resembling that of brutes. But there is reason to believe, that the tribes in closest contact with European settlers are more miserable and savage than those of the interior; and even with respect to these, increasing acquaintance with their language, and a consequent improved insight into their modes of

thought, tend to raise the very low estimate which has been formed and long maintained, in regard to their extreme mental degradation. The latest and most authentic statements enable us to recognize among them the same principles of a moral and intellectual nature, which, in more cultivated tribes, constitute the highest endowments of humanity; and thus to show that they are not separated by any impassable barrier, from the most civilized and elevated nations of the globe.—There are many indications, indeed, that the Negrito race is not so radically distinct from the Malayo-Polynesian, as the marked physical dissimilarity of their respective types, and the apparent want of conformity between their languages, would make it appear. For as, on the one hand, some of the subdivisions of the latter present a decided tendency towards that prognathous character and depth of complexion which are typical of the former, so among the former do we not unfrequently meet with a lighter shade of skin, a greater symmetry of skull, and a considerable improvement in form and feature. And although no very close relationship can be discovered between the Negrito and Malayo-Polynesian languages, yet it has been pointed-out by Mr. Norris that a much more decided relationship exists between the Australian and Tamulian (§ 954); and remote as this connection seems, the circumstance adds weight to the idea, that the native Australians (with other Negrito tribes) are an offset from that southern branch of the great nomadic stock of Central Asia, which seems early to have spread itself through the Indo-Chinese and the Indian Peninsulas, and to have even there shown an approximation to the prognathous type.*

963. Looking, then, to the great diversity which exists among the subordinate groups of which both these divisions consist, and their tendency to mutual approximation, it cannot be shown that any sufficient reason exists for isolating them from each other; and, as already remarked (§ 961), there seems no medium between the supposition that each island had its aboriginal pair or pairs, and the doctrine that the whole of Oceania has been peopled from a common stock. Looking, again, to the very decided approximation which is presented by certain Oceanic tribes to the Mongolian type, and this in localities which, on other grounds, might be regarded as having received the first stream of migration, the possibility, to say the least, can scarcely be denied, that the main-land furnished the original stock, which has undergone various transformations subsequently to its first dispersion; these having been the result of climatic influence and mode of life, and having been chiefly influenced as to degree, by the length of time during which the transforming causes have been in operation. At any rate it may be safely affirmed, that the Oceanic races are not entitled by any distinctive physical peculiarity, to rank as a group which must have necessarily had an original stock distinct from that of the Continental nations.

* Some very interesting speculations, based on the most recent information, respecting the mode in which the great Oceanic region has been peopled, are put-forth by Dr. Latham on "Orr's Circle of the Sciences," vol. i., pp. 341–349

CHAPTER XVIII.

OF THE MODES OF VITAL ACTIVITY CHARACTERISTIC OF DIFFERENT AGES.

964. Although from the time when the Human being comes into the world, to the final cessation of his corporeal existence, the various functional operations of Organic life are carried-on with ceaseless activity, whilst those of Animal life are only suspended by the intervals of repose which are needed for the renovation of their organs, yet there are very marked differences, not only in the *degree of their united activity*, but also in the *relative degrees of energy which they severally manifest*, at different epochs. These differences, taken in connection with the modifications in the size and conformation of the body with which they are in relation, mark out the whole term of life into the various 'Ages,' which are commonly recognized as seven, namely Infancy, Childhood, Youth, Adolescence, Manhood, Decline, and Senility. For Physiological purposes, however, a less minute subdivision is equally or perhaps more appropriate; namely the three great periods of *Growth and Development*, of *Maturity*, and of *Decline*. The first comprehends the whole of that series of operations, by which the germ evolves itself, at the expense of the nutriment which it appropriates from external sources, into the complete organism, possessed not merely of its full dimensions, but of its highest capacity for every kind of functional activity; this includes, therefore, the epochs of Embryonic life, Infancy, Childhood, Youth, and Adolescence, all of which are characterized by an *excess* of the *constructive* over the *destructive* changes taking place in the organism. The second period ranges over the whole term of Manhood, in which, the organism having attained its complete development, is brought into vigorous and sustained activity; and in which it is *maintained* in a condition fitted for such activity, by the equilibrium which subsists between the operations of redintegration and of disintegration. The third period commences with the incipient failure of the bodily powers, consequent upon the *diminished* activity of the *constructive* powers, as compared with that of the changes which involve *degeneration* and *decay*; this diminution begins to manifest itself during the latter part of Middle Life, before Old age can properly be said to commence; and it continues in an increasing ratio, through the whole 'decline of life,' until, the reparative powers being exhausted, Death supervenes as the necessary termination of that long succession of phenomena of which Life consists.

965. Although the organisation of the body at each epoch may be truly said to be the *resultant* of all the *material* changes which it has undergone during the preceding periods, yet it is scarcely possible to take an enlarged view of the case, without perceiving that we must look for the cause of this succession in those *dynamical* conditions, the presence of which is the distinguishing attribute of living structures. Every *constructive* act, whether this consist in Growth (§ 431) or in Development (§ 342),

not merely requires *materials* for the new tissue produced, but depends upon the active operation of a *formative power*, without whose agency these materials would remain unorganized. When we examine (see PRINC. OF GEN. PHYS.) into the source of the formative power which we see thus operating in every individual organism, we find that it is chiefly traceable to the *Physical* Forces to which it is subjected (Heat being the one which seems to bear most directly upon the formative operations), these forces being metamorphosed, so to speak, into the constructive force of the living body, in virtue of the peculiar endowments of *its* material substratum,—just as an Electric current transmitted through the different nerves of Sense, produces the sensory impressions which are characteristic of each respectively (§ 731), or as the same current, transmitted through one form of Inorganic matter, produces Light and Heat, through another, Chemical Change, or through another, Magnetism. But we must also recognize in the Organism at large, as well as in every integral part of it (§ 340), a certain *capacity* for growth and development,—which is the original endowment of its *germ*,—which not only determines the mode in which it shall progressively evolve itself into the fabric characteristic of its species and sex, but also shapes the peculiarities of the individual,—which serves also to bring-about the perpetual reconstruction that is needed for its continued maintenance, and is peculiarly manifested in those reparative processes which make-good losses of its substance resulting from injury or disease,—and of which the cessation, by preventing any further metamorphosis of Physical into Vital force, causes the constructive powers to fail altogether, so that the Organism is resolved back by these very forces, into the various forms of Inorganic matter at the expense of which it had been built-up.

966. Now this 'germinal capacity' is most strikingly displayed during those earliest periods of existence, in which growth and development alike are taking place most rapidly; in fact, the further we go back in the history of intra-uterine life, the more energetic do we perceive its manifestations to be. For when we look simply at the *increase* from the minute point that constitutes the first perceptible germ, to the mature fœtus of 6 or 7 lbs. weight, we see that at no other period of existence can that increase be compared in its rate, with that which presents itself during the nine months that follow conception, and if we go more into detail, we find that it is yet more remarkable in the earlier than in the later months (§ 968). So, again, it is in the first few weeks of embryonic life, that the foundation is laid of most of its permanent *organs*, in the midst of an apparently homogeneous mass of cells, whilst in the succeeding weeks, these rudiments are evolved into the semblance of the forms they are subsequently to present, and a differentiation of *tissues* begins to show itself in their several parts; so that the developmental process is so far advanced at little more than half the term of gestation, that the fœtus may even then, under favourable circumstances, maintain an independent existence (§ 876). The rate of increase becomes progressively slower, during the advance from infancy to maturity, and the energy of the developmental processes is comparatively enfeebled, being limited to the perfecting of structures whose foundations had been previously laid, and in no instance manifesting itself normally in the evolution of a new part or organ. Now as there is no limit (in the well-nourished indi-

vidual) to the supply of Food and Warmth, it follows that this gradual decline of formative activity must be due to a diminution of the *capacity* for that activity, inherent in the organism itself; and this diminution is still more strongly marked by that entire cessation, both of increase, and of further developmental changes, which constitutes the termination of the first period. For the organism which has attained that stage of its existence, has so far lost the formative capacity which characterized its earlier years, that, however copious the supply of food, however abundant the generation of heat, it can thenceforth do no more than *maintain* its normal condition, and can effect this for only a limited term of years. It seems a necessary sequence of this series of phenomena, that the time should come, when, after a period of gradual decline, the germinal capacity of the organism should be so much reduced as no longer to suffice for the maintenance of its own integrity; and whenever such is the case, the termination of its existence as a living body must be the necessary result. Hence we find that there is a natural limit, not only to the size and development of the organism, but also to the duration of its life. And although that limit, in each case, is subject to variation amongst *individuals*, partly in consequence of diversity of external conditions, but partly (it may be surmised) through differences in the measure of germinal capacity possessed by each, yet there is a limit also to these variations, so that the character of the *species* is never departed from.

967. *Period of Growth and Development.*—The general history of the first part of this period, that of Embryonic existence, has already been so fully given, that it is only necessary here to remark briefly in regard to the character of its vital operations, that the whole nisus of its activity is directed rather to the performance of the *vegetative* or *organic* than to that of the *animal* functions, the action of the heart, and the occasional reflex movements of the limbs, being its only manifestations of nervo-muscular power. And thus it seems to be, that the formative capacity is greater during embryonic life, than at any subsequent period, and greater in its earlier than in its later stages; so that we have not only evidence of an extraordinary power of regenerating parts which have been lost by disease or accident, as seen in attempts at the reproduction of entire limbs after their 'spontaneous amputation' (§ 359); but there is also not unfrequently an absolute excess of productive power, as shown in the development of supernumerary organs, which may even proceed to the extent of the complete duplication of the entire body, by the early subdivision of the embryonic structure into two independent halves (§ 355).—It is to be noticed, also, that the embryo derives its supply not merely of food but also of *heat*, from its maternal parent, and it is probably owing especially to the constancy with which this force operates, that the period of embryonic development is so uniform in Man (as in warm blooded Animals generally), by comparison with the corresponding developmental periods in Plants and cold blooded Animals, these being entirely determined by the degree of heat to which the embryoes are subjected.

968. It is frequently of great importance, both to the Practitioner and to the Medical Jurist, to be able to determine the *age* of a Fœtus, from the physical characters which it presents, and the following table has been framed by Devergie* in order to facilitate such determination. It

* "Médecine Légale," 3ième edit tom i. p. 279.

is to be remarked, however, that the *absolute length* and *weight* of th Embryo are much less safe criteria, than its *degree of development*, as in dicated by the relative evolution of the several parts which make the appearance successively. Thus it is very possible for one child, born a the full time, to *weigh* less than another, born at 8 or even at 7 month its *length*, too, may be inferior: and even the position of the *middle poi* of the body is not, taken alone, a safe criterion, since it is liable to varia tion in individuals.*

Embryo 3 to 4 weeks.—It has the form of a serpent;—its length from 3 to 5 lines;—i head indicated by a swelling;—its caudal extremity (in which is seen a white line, indi cating the continuation of the medulla spinalis), slender, and terminating in the umbilical cord;—the mouth indicated by a cleft, the eyes by two black points;—members beg to appear as nipple-like protuberances;—liver occupies the whole abdomen;—the blad is very large. The chorion is villous, but its villosities are still diffused over the whol surface.

Embryo of 6 weeks.—Its length from 7 to 10 lines;—its weight from 40 to 75 grain face distinct from cranium;—aperture of nose, mouth, eyes, and ears perceptible;—he distinct from thorax;—hands and fore-arms in the middle of the length, fingers distinc legs and feet situated near the anus;—clavicle and maxillary bone present a point o ossification;—distinct umbilicus for attachment of cord, which at that time consists of th omphalo-meseraic vessels, of a portion of the urachus, of a part of the intestinal tube, an of filaments which represent the umbilical vessels. The placenta begins to be formed;— the chorion still separated from the amnion; the umbilical vesicle very large.

Embryo of 2 months.—Length from 16 to 19 lines;—weight from 150 to 300 grains;— elbows and arms detached from the trunk;—heels and knees also isolated;—rudiments o the nose and of the lips;—palpebral circle beginning to show itself;—clitoris or pe apparent;—anus marked by a dark spot;—rudiments of lungs, spleen, and supra-ren capsules;—cæcum placed behind the umbilicus;—digestive canal withdrawn into th abdomen;—urachus visible;—osseous points in the frontal bone and in the ribs. Chori commencing to touch the amnion at the point opposite the insertion of the placenta. pl centa begins to assume its regular form;—umbilical vessels commence twisting.

Embryo of 3 months.—Length from 2 to 2½ inches;—weight from 1 oz. to 1½ oz. (Tro —head voluminous;—eyelids in contact by their free margin;—membrana pupillaris vi ble;—mouth closed;—fingers completely separated;—inferior extremities of greater leng than rudimentary tail;—clitoris and penis very long;—thymus as well as supra-ren capsules present;—cæcum placed below the umbilicus;—cerebrum 5 lines, cerebellum lines, medulla oblongata 1½ line, and medulla spinalis ⅔ of a line, in diameter;—tw ventricles of heart distinct. The decidua reflexa and decidua uterina in contact;—[illegible] contains umbilical vessels and a little of the gelatine of Wharton;—placenta complet isolated;—umbilical vesicle, allantois, and omphalo-meseraic vessels have disappeared

Fœtus of 4 months.—Length 5 to 6 inches;—weight 2½ to 3 oz.;—skin rosy, tol rab dense;—mouth very large and open;—membrana pupillaris very evident;—nails begin appear;—genital organs and sex distinct;—cæcum placed near the right kidney;—[illegible] bladder appearing;—meconium in duodenum;—cæcal valve visible;—umbilicus placed near pubis;—ossicula auditoria ossified;—points of ossification in superior part of sacr membrane forming at point of insertion of placenta on uterus;—complete contact chorion with amnion.

Fœtus of 5 months.—Length 6 to 7 inches;—weight 5 to 7 oz.;—volume of head st comparatively great;—nails very distinct;—hair beginning to appear;—skin without seb ceous covering;—white substance in cerebellum;—heart and kidneys very voluminous;— cæcum situated at inferior part of right kidney;—gall-bladder distinct;—germs of pe manent teeth appear;—points of ossification in pubis and calcaneum;—meconium has yellowish-green tint, and occupies commencement of large intestine.

Fœtus of 6 months.—Length 9 to 10 inches;—weight 1 lb.;—skin presents an appearance of fibrous structure;—eyelids still agglutinated, and membrana papil remains;—sacculi begin to appear in colon;—funis inserted a little above pubis;—[illegible]

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* See, on this last point, Moreau in "Lancette Française," 1837; and Dr. A. Tayl in "Guy's Hospital Reports," 1842.

a purplish red;—hair white or silvery;—sebaceous covering begins to present itself;—meconium in large intestine;—liver dark red;—gall bladder contains serous fluid destitute of bitterness;—testes near kidneys;—points of ossification in four divisions of sternum;—Middle point at lower end of sternum.

Fœtus of 7 months.—Length 13 to 15 inches;—weight 3 to 4 lbs.;—skin of rosy hue, thick, and fibrous;—sebaceous covering begins to appear;—nails do not yet reach extremities of fingers;—eyelids no longer adherent;—membrana pupillaris disappearing;—a point of ossification in the astragalus;—meconium occupies nearly the whole of large intestine;—valvulæ conniventes begin to appear;—cæcum placed in right iliac fossa;—left lobe of liver almost as large as right;—gall bladder contains bile;—brain possesses more consistency;—testicles more distant from kidneys;—middle point at a little below end of sternum.

Fœtus of 8 months.—Length 14 to 16 inches;—weight 4 or 5 lbs.;—skin covered with well marked sebaceous envelope;—nails reach extremities of fingers;—membrana pupillaris becomes invisible during this month;—a point of ossification in last vertebra of sacrum;—cartilage of inferior extremity of femur presents no centre of ossification;—brain has some indications of convolutions;—testicles descend into internal ring;—middle point nearer the umbilicus than the sternum.

Fœtus of 9 months, the full term.—Length from 17 to 21 inches;—weight from 5 to 9 lbs., the average probably about 6½ lbs.;—head covered with hair in greater or less quantity, of from 9 to 12 lines in length;—skin covered with sebaceous matter, especially at bends of joints;—membrana pupillaris no longer exists;—external auditory meatus still cartilaginous;—four portions of occipital bone remain distinct;—os hyoides not yet ossified;—point of ossification in the centre of cartilage at lower extremity of femur;—white and grey substances of brain become distinct;—liver descends to umbilicus;—testes have passed inguinal ring, and are frequently found in the scrotum;—meconium at termination of large intestine;—middle point of body at umbilicus, or a little below it.

909. From the time of its entrance into the world, the condition of the Human Infant is essentially changed. It is no longer supplied with nutriment by the direct transmission of organizable materials from the circulating fluid of the mother to its own; but obtains it by the processes of digestion, absorption, and assimilation, which involve the establishment of new modes of vital activity in its own organism. In order, however, that the change may not be too sudden, the nutriment provided by Nature for the early period of infantile life, is such as to occasion the least possible demand upon its vital powers, for the preparation of the organizable material which is required for its further growth and development. But the transition is a most important one in another particular; the infant is now thrown in a great degree upon its own resources for the generation of its Heat; and this it is enabled to accomplish by the combustion of a portion of its food which is specially provided for the purpose, this combustion being promoted by the arrangements for that active Respiration, which now supersedes the very limited aeration of its circulating fluids that was sufficient during fœtal life. In the movements of the respiratory muscles and of the walls of the alimentary canal, we have a new source of expenditure of vital force, and of destruction of tissue; and this expenditure is progressively augmented, as the motions of the body and limbs become increasingly active. Thus we find that the formative powers are not exercised during Infancy and Childhood, solely in the *construction* and *augmentation* of the fabric (as they were during embryonic life), since there is a constant demand upon them for its *maintenance*; and this demand becomes greater and greater, in proportion to the activity of the Animal powers. These, at first called into exercise by the stimulus of sensory impressions upon the Nervous system (§ 591), are speedily brought into very energetic operation. This operation is of an extremely limited character, being at first purely

sensorial, and for some time afterwards simply *perceptive* (§ 603). By the *whole Mind* (such as it is) being given-up to it, *habits of observation* are formed, which are never subsequently lost; the infant learns *how to use* his Organs of Sense, and he also acquires those powers of *interpreting* their indications, which become so completely engrafted in his nature, as henceforth to seem a part of it. Although this Education of the Senses will necessarily go-on, even without any intentional assistance on the part of others, yet it is in the power of the Mother or Nurse to promote it effectually, by supplying objects of various kinds which the Infant may look-at and grasp, and by not abruptly interfering (by the too-speedy withdrawal of such objects) with the process by which the visual and tactile perceptions are blended and harmonized (§ 758). The Nervous system of the Infant, although thus called into extraordinarily energetic activity, cannot long sustain that activity; a very large measure of Sleep is required for the restoration of its speedily-exhausted powers; and any unusual excitement of them tends to injurious disturbance of its nutrition. It is owing to this peculiar susceptibility of the Nervous system of the Infant to external influences, that medicines (especially narcotics) which exert a special influence upon that system, are so peculiarly potent in their effects at this period of life, that the greatest caution is needed in their administration.

970. The most important developmental change which occurs in Infancy, after the complete establishment of the extra-uterine circulation (§ 897), is the completion and eruption of the first set of Teeth, the greater part of whose formation, however, has taken place before birth. These 'milk' or 'deciduous' teeth, 20 in number, usually make their appearance in the following order. The four central Incisors first present themselves, usually about the 7th month after birth, but frequently much earlier or later; those of the lower jaw appear first. The lateral Incisors next show themselves, those of the lower jaw coming through before those of the upper; they usually make their appearance between the 7th and 10th months. After a short interval, the anterior Molars present themselves, generally soon after the termination of the 12th month; and these are followed by the Canines, which usually protrude themselves between the 14th and 20th months. The posterior Molars are the last, and the most uncertain in regard to their time of appearance; this varying from the 18th to the 36th month. In regard to all except the front teeth, there is no settled rule as to the priority of appearance of those in the upper or under jaw; sometimes one precedes, and sometimes the other; but in general it may be stated, that whenever one makes its appearance, the other cannot be far off. The same holds-good in regard to the two sides, in which development does not always proceed exactly *pari passu*. The period of Dentition is sometimes one of considerable risk to the Infant's life; and this especially when an irritable state of the nervous system has been brought-about by unsuitable food, unwholesome air, or some other cause of disordered health. In such cases, the pressure upon the nerves of the gum, which necessarily precedes the opening of the sac and the eruption of the tooth, is a fruitful source of irritation, producing disturbance of the whole system, and giving origin to Convulsive affections, which are not unfrequently fatal. These have been particularly studied by Dr. M. Hall, who recommends the free use of the gum-lancet

as a most important means of prevention and cure; but the Author has no doubt that too much attention has been given to the immediate source of the irritation, and too little to the general state of the system, and that constitutional treatment, especially change of air, and improvement of the diet, is of fundamental importance. In infants whose general health is good, and who are not over fed, Dentition is usually a source of but very trifling disturbance, a slight febrile action, lasting only for a day or two, being all that marks the passage of the tooth through the capsule, and its eruption through the gum taking-place without the least indication of suffering or disorder. Any existing malady or abnormal tendency, however, is pretty sure to be aggravated during the 'cutting of the teeth;' and it is therefore of the greatest consequence, that the infant should be withdrawn during this period from all injurious influences, and that no irregularity of diet, or deficiency of fresh air and exercise, should operate to its disadvantage.

971 Although there are no well marked divisions between the periods of Childhood, Youth, and Adolescence, through all of which we witness the continuance of the processes of Growth and Development (though in a gradually-decreasing ratio), yet we may appropriately distinguish each as the epoch of one of those important changes which tend towards the completion of the fabric, namely, *Childhood* as ranging through the greater part of the period of the second Dentition,—*Youth* as characterized by that increased evolution of the sexual organs, and by those general constitutional changes accompanying that evolution, which altogether constitute Puberty,—and *Adolescence* as distinguished by that entire consolidation of the Osseous skeleton, which is not completed until the full stature has been attained. It will be convenient first to consider what is common to all these periods; and then to notice the features by which they are severally characterized.

972 The passage from Infancy to Childhood may be regarded as marked by the eruption of the 'deciduous' Teeth; by the termination of that direct supply of food to the offspring, which is afforded until then by the Mammary secretion of the mother; by the dawn of the Intellectual powers, manifested in the first efforts at speaking; and by the acquirement of sufficient control over the muscular apparatus, to render it subservient to the increasing desire which then displays itself for independent Locomotion. All these advances usually take place simultaneously, or nearly so, during some part of the second year; some Infants being much more forward than others, both in 'cutting their teeth' and in learning to walk and to talk. When they have been completed, the Child enters upon a life which is in many respects new. The alteration of its diet involves a much higher activity of all the organs which are concerned in making blood; whilst its greatly-increased amount of exertion, both of body and mind, gives occasion to a more rapid disintegration of the nervous and muscular tissues, and hence to a higher activity of the Excretory organs. This will, of course, progressively augment, in proportion as the Nervo-muscular apparatus is brought, with advancing years, into more vigorous and more prolonged exercise; until, with the attainment of adult age, the disintegration of these tissues comes to be the chief source of the Excrementitious products. But during the whole period of increase, there is another source of demand for nutritive activity,

in that perpetual *re-construction* of the fabric (involving a sort of continual pulling-down and rebuilding on a larger scale, all the old material being carried-away as useless), which is a necessary condition of its growth; but this demand of course slackens with the diminution of the rate of increase, and at last it ceases altogether, just when the other attains its maximum. Hence the demand for food, on the one hand, and the amount of excretory matter set-free from the body, on the other, are remarkably large during the whole of this period; the child, as every one knows, consuming far more nutriment than the adult, in proportion to the weight of their respective bodies; and the like being true of the quantity of carbonic acid exhaled from the lungs (§ 316 III), and of the urea given-off from the kidneys (§ 411).—That the germinal capacity, though inferior to that of the embryo, still persists in a high degree during the period of childhood and youth, is shown in the readiness with which the effects of injuries and disease are recovered from; for although the regeneration of lost parts does not take-place to nearly the same extent as during early embryonic life, yet, up to a certain point, it is effected with great completeness, and with much greater rapidity than at later epochs. It is still, in fact, rather in the exercise of formative power, than in the production of nervo-muscular vigour, that the vital force of the earlier part of this period is displayed; and we may readily trace such a relation of reciprocity between these two modes of its manifestation, as is strongly indicative of the community of their source. For it is familiar to every observer, that, when the growth of a child or a young person is peculiarly quick, his nervo-muscular energy is usually feeble, and his power of endurance brief, in comparison with that which can be put-forth by one whose frame is undergoing less rapid increase. And we observe, moreover, that the capacity of resistance to depressing influences of various kinds, which is a no less decided manifestation of the vital power of the organism (seeing that these influences are of the kind which *tend towards* its death), is possessed by the latter in a far higher degree than by the former. This is remarkably the case in regard to privation of food and depression of external temperature; under which, too, children and young persons succumb much more speedily than adults.

973. It is most interesting to trace, during the progress of the development of the bodily fabric, the gradual expansion and invigoration of the Mental powers. The acquirement of Language, as already remarked (§ 613), constitutes the most important step in the development of the *ideational* consciousness; and it is easy to recognize in the psychical manifestations of Children, the further progress of that development. The formation of *Associations* between ideas (§§ 632–638) takes-place with extraordinary readiness and tenacity during the earliest period of childhood; and these exercise so much influence over the succession of the thoughts during the whole remainder of life, that "the force of early associations" has become proverbial. Out of these associations arise, on the one hand, Memory (§ 642) and Imagination (§ 648); on the other hand, those simple processes of Reasoning (§ 646) which are necessary to the development of a higher class of ideas. Thus the mind passes from those primary notions of individual objects which are directly suggested by sense-perceptions, to those *abstract* ideas of their qualities, which

enable them to recognize those qualities elsewhere, notwithstanding the existence of differences in other respects, and thence to those *general ideas*, in which the abstractions are embodied (§ 646). In all these processes, the child-mind seems to be so entirely concentrated upon the particular subject of its thoughts, as to be 'possessed' by it for the time, almost as completely as a 'biologized' subject is by his dominant idea (§ 672), and no prolonged study of it is required to justify the statement, that its operations are for some time entirely *automatic*, and that the acquirement of Volitional control over them, on the part of the individual, is a very gradual process (§ 677). As a general rule it may be laid down, that the activity with which the formation of new ideas takes-place in the child, and the rapidity with which the attention transfers itself from one object to another, prevents any single state from fixing itself durably in the consciousness, so that the Memory preserves but faint traces of the greater part of what passes through the mind, and it is (for the most part) only when the same thoughts are frequently recurred-to, that they take root (so to speak) in the psychical nature. Still we occasionally find that particular impressions exert a very powerful influence on the subsequent course of thought and feeling, and there is good reason to believe, that even where the *consciousness* loses its hold over them, impressions of a transient nature may leave such traces in the Brain, that they may be reproduced at any future time, when the appropriate suggestion may happen to be supplied (§ 642).—Whilst the ideational consciousness is thus being expanded and elevated, the *Emotional* part of the Psychical nature is rapidly acquiring a greater range and intensity of action. The infant and young child give ample evidence in their actions, of the several forms of Emotional Sensibility which connect themselves with Sensational and Perceptive states (§§ 602, 607, 609), but no sooner does the development of Ideas commence, than the various modifications of 'feeling' attach themselves to *these* (§ 619); and thus almost every thought that is not a purely-intellectual abstraction, comes to possess more or less of an Emotional character. Here, again, we trace the powerful influence of early impressions; for notwithstanding that the state of feeling which is habitual to each individual, may depend in great degree upon his original constitution, yet it is unquestionable that it is largely influenced (especially in its association with particular classes of ideas) by *sympathy* with the like states in those among whom the child receives its early education (§ 609). It is of peculiar importance, therefore, that this example should be such as it is wholesome for the child to imitate; since it is upon the habits of feeling thus early formed, that the happiness and right conduct of after-life mainly depend. This statement (which applies with yet greater force to the Moral Sense) may at first seem inconsistent with the well-known fact, that the Emotions of children are peculiarly transient in their character, even when they are violently excited; one state of feeling giving-place to another, even of the most opposite kind, under the influence of some new impression, or of some change in the direction of the ideas. But the same general principle applies to this case, as to the formation of habits of thought; namely, that although individual impressions are more speedily dissipated from the minds of children than from those of adults, yet that when impressions of the same kind are frequently repeated, the

brain *grows-to* them in such a manner, that they come to take-part (as it were) in its ordinary working, and thus, by establishing a particular mode of nutritive assimilation, they tend to *perpetuate* this acquired habit, of whatever nature it be.—The right training of the Emotional tendencies, and all the higher uses of the Intellectual Faculties, depend in great degree, as already shown (§ 669), upon the influence of the Will in directing the current of thought and feeling; and this becomes greater and greater, if rightly cultivated, with the advance of years, so that the psychical powers, whilst themselves acquiring an increase of vigour and comprehensiveness, are brought more and more under the control of the individual, and can be utilized in any way in which he may choose to employ them. Thus with a diminishing *mobility* of thought and *excitability* of feeling, the Mind becomes more and more capable of *sustained* and *determinately-concentrated* activity; and is at the same time progressively acquiring that store of familiar *experiences*, which not only constitutes the basis of all attainments in special departments of knowledge, but supplies (when judiciously used) that 'common sense' by which we form most of our judgments and direct most of our conduct.—During this period, moreover, the Muscular apparatus of Animal life, whose actions are at first purely automatic, is brought more and more under the direction of the Mind, so as to express its ideas, its feelings, and its volitions. And it is whilst this transference is going-on, that new habits of action are most readily formed, and, when once formed, are durably impressed upon the organism (§§ 514, 550, 794).—The excess which must exist, during the whole of this period, in the *constructive* over the *destructive* activity, and the large amount of the latter which (as already shown) arises out of the very nature of Growth, in addition to that which proceeds from the increased activity of the Animal functions, necessitates a much larger proportion of repose than suffices for the adult; but this necessity diminishes with the progress of years, for the reasons already mentioned, and thus we find that whilst the young child passes 16 or 18 hours a day in sleep, half that time suffices for the youth just entering on manhood.

974. The *Second Dentition*, consisting in the replacement of the *deciduous* or 'milk' Teeth by the *permanent* Teeth that succeed them, which is the most important developmental change that occurs during the period of Childhood, normally commences in the 7th or 8th year; the germs of the new teeth, however, are formed long previously, having their origin in a process of gemmation from the tooth-sacs of the temporary teeth, which takes-place at a very early period in the development of the latter. The three permanent Molars on either side of each jaw, however, have no such origin: since they do not replace temporary teeth. The first pair, which usually make their appearance behind the temporary molars, either contemporaneously-with, or a little anteriorly-to, the first shedding of the deciduous teeth, are really 'milk' teeth, so far as their origin is concerned, since they are developed from primitive tooth-sacs; on the other hand, the second true molars, which afterwards come-up behind them, are evolved from tooth-sacs which hold the same relation to those of the first, as the tooth-sacs of the other permanent teeth do to those of the deciduous teeth which they replace; and the third true molars, or *dentes sapientiæ*, bear the like relation to the second. Although

the eruption of the true molars is so long postponed, yet the foundation of them is laid at an early period, for the papilla of the *first* is distinguishable at the 16th week after conception, that of the second at the 7th month after birth, and that of the third at the 6th year. In the successive replacement of the 'milk' teeth by the 'permanent' set, a very regular order is usually followed. The middle Incisors are first shed and renewed, and then the lateral Incisors. The anterior 'milk' Molars next follow; and these are replaced by the anterior Bicuspid teeth. About a year afterwards, the posterior 'milk' Molars are shed, and are replaced in like manner by Bicuspid teeth. The Canines are the last of the 'milk' teeth to be exchanged; in the succeeding year, the second pair of the true Molars appears; but the third pair, or *dentes sapientiae*, are seldom developed until three or four years subsequently, and often much later.

975. It has been proposed* (and, from the evidence adduced in its favour, the proposition would seem entitled to considerable attention) to adopt the successive stages in the Second Dentition, as standards for estimating the physical capabilities of Children, especially in regard to those two periods which the Factory Laws render it of the greatest importance to determine: namely, the ages of *nine* and *thirteen* years. Previously to the former, a Child is not permitted to work at all; and up to the latter, it may be only employed during nine hours a day. The necessities or the cupidity of Parents are continually inducing them to misrepresent the ages of their children; and it has been found desirable, therefore, to seek for some test, by which the capability of the Child may be determined, without a knowledge of its age. A standard of Height has been adopted by the Legislature for this purpose; but upon grounds which, physiologically considered, are very erroneous; since, as is well known, the tallest children are frequently the weakest (§ 972). According to Mr. Saunders, the degree of advance of the Second Dentition may be regarded as a much more correct standard of the degree of general development of the organic frame, and of its physical powers; and it appears from his inquiries, that it may be relied-on as a guide to the real age, in a large proportion of cases; whilst no serious or injurious mistake can ever arise from its use. It may happen that local or constitutional causes may have slightly retarded the development of the Teeth; in which case the age of the individual would rather be under-estimated, and no harm could ensue: on the other hand, instances of premature development of the Teeth very rarely, if ever, occur; so that there is little danger of imputing to a Child a capability for exertion which he does not possess, as the test of height is continually doing. Moreover, if such an advance in Dentition should occur, it might probably be regarded as indicative of a corresponding advance in the development of the whole organism; so that the real capability would be such as the teeth represent it.—The following is Mr. Saunders's statement of the Ages, at which the 'permanent' Teeth respectively appear. The first true Molars usually present themselves towards the end of the 7th year. Occasionally one of them protrudes from the gum at 6, or more frequently at $6\frac{1}{2}$ years of age; but the evolution of the whole of them may be regarded as an almost

* "The Teeth a Test of Age, considered with reference to the Factory Children." By Edwin Saunders.

infallible sign of the Child's being 7 years old. In other instances, whe the tooth on one side of the mouth is freely developed, it is fair to recko the two as having emerged from their capsule; since the development o the other must be considered as retarded. This rule only holds good however, in regard to teeth in the same row; for the development of th teeth in either jaw must not be inferred from that of the correspondin teeth in the other. With this understanding, the following table wil probably be very near the truth:—

Central Incisors developed at	8 years.
Lateral Incisors	9 ,,
First Bicuspid	10 ,,
Second Bicuspid	11 ,,
Canines	12 to 12½
Second Molars	12½ to 14

The following are the results of the application of this test, in a larg number of cases examined by Mr. Saunders. Of 708 children of nin years old, 530 would have been pronounced by it to be near the comple tion of their *ninth* year; having the central, and either three or four lateral incisors fully developed. Out of the remaining 178, it would have indi cated that 126 were 8½ years old, as they presented one or two of th lateral Incisors, and the 52 others would have been pronounced 8 year old, all having three or four of the central Incisors. So that the extrem deviation is only 12 months, and this in the inconsiderable proportio (when compared with the results obtained by other means) of 52 in 70 or 7½ per cent. Again, out of 338 children of 13 years of age, 294 migh have been pronounced with confidence to be of that age; having th Canines, Bicuspid, and second Molars, either entirely developed, or wit only the deficiency of one or two of either class. Of the 44 others, 3 would have been considered as in their 13th year, having one of the pos terior Molars developed; and 8 as near the completion of the 12th having two of the Canines, and one or two of the second Bicuspid. I all these instances, the error is on the favourable side,—that is, on th side on which it is calculated to prevent injury to the objects of th inquiry; in no instance did this test cause a Child to be estimated a older or more fit for labour than it really was.*

976. The period of *Youth* is distinguished by that advance in the evo lution of the Generative apparatus in both sexes, and by that acquiremen of its power of functional activity, which constitutes the state of *Puberty* Of the principal changes in which this consists, in the two sexes respec tively, an account has already been given (§§ 846, 852, 915), and it

* The value of this test, as compared with that of Height, is manifested by a strik example adduced by Mr Saunders. The height of one lad, J. J., aged 8 years and months, was 4 feet and ¾ of an inch, that of another boy, aged 8 years and 7 months, w only 3 feet 7¼ inches. According to the standard of height adopted by the Factory Com missioners (namely 3 feet 10 inches), the *taller* lad would have been judged fit for e whilst the *shorter* would have been rejected. The Dentition of the latter, however, w further advanced than that of the former, for he had two of the lateral Incisors, wh the former had only the central; and the determination of their relative physical p which would have been thus formed, would have been in complete accordance with t truth. The elder boy, though shorter than the other by 5¼ inches, possessed a gre greater degree both of corporeal and mental energy, and his pulse was strong and regul whilst that of the younger lad, who was evidently growing too fast, was small and fr quent. An instance even more striking has come under the Author's own observation.

merely requisite here to add, that this augmented development can only be rightly regarded as *preparatory* to the exercise of these organs, and not as showing that the aptitude for their exercise has already been fully attained. It is only when the growth and development of the *individual* are completed, that the procreative power can be properly exerted for the continuance of the *race*; and all experience shows, that by prematurely and unrestrainedly yielding to the sexual instincts, not merely the generative power is early exhausted, but the vital powers of the organism generally are reduced and permanently enfeebled; so that any latent predisposition to disease is extremely liable to manifest itself, or the bodily vigour, if for a time retained with little deterioration, early undergoes a marked diminution.

977. After the attainment of Puberty, no marked alteration takes-place in the organism, save the continuance of its increase in stature, usually for a few years longer (§ 914); which increase is the chief manifestation of the excess of the germinal capacity, that has not yet expended itself in the building-up of the fabric. But so long as this increase is going-on, there is a want of that solidity and compactness of the organism, which seem only attainable when growth has ceased; and the attainment of which, being essential to the highest manifestations of vigour and endurance, marks the final completion of its development. Of this we have the best illustration in the *Osseous* system, whose completion, being postponed until all further *growth* has ceased, may be fairly considered as marking the final stage in the development of the organism, and as therefore characterizing the period of *Adolescence*.—Commencing with the *Vertebral Column*, we find that whilst the 'body' and 'neural arches' of each vertebra become consolidated in early childhood, the spinous and transverse processes are completed by separate 'epiphyses,' the ossification of which does not commence until after puberty, and the final union of which with the body of the bone may not occur until the age of twenty-five or thirty years. About the same time, there is formed and added to each surface of the body of the vertebra, a smooth annular plate of solid bone, which covers a portion that was previously rough and fissured. During this period, the consolidation of the Sacrum is proceeding; the component vertebræ of which remain separate up to about the sixteenth year, and then begin to unite from below upwards, the union of the two highest being completed by about the twenty fifth or the thirtieth year; whilst at the same time, thin osseous plates are formed on either side of the coalesced mass, which seem to represent the epiphyses of the transverse processes of its component vertebræ, and like them are finally joined-on to the body of the bone. The ossification and coalescence of the Coccygeal vertebræ takes-place at a still later period. Each Rib in like manner, has two epiphyses, one for the head and the other for the tubercle; the ossification of which begins soon after puberty, whilst their union with the body of the bone is not completed until some years afterwards. The five pieces of which the Sternum consists, though themselves completely ossified, remain separate until after the age of puberty; when their union commences from below upwards, as in the sacrum, not being always completed, however, even in old age, by the junction of the first piece to the rest of the bone. The ossification of the Ensiform cartilage does not commonly begin until after the age of puberty; and it is

usually not entirely completed, even in very advanced life.—The ossific union of the separate elements of the *Bones of the Skull* (§ 908) is usually completed within a few years after birth; but there are some parts, which not unfrequently remain distinct during the greater portion of life, and which may even never coalesce; such is the case with the two halves of the Frontal bone, which often remain permanently divided by a continuation of the sagittal suture, and with the Styloid process of the temporal bone. In the *Upper Extremities*, we find the Scapula presenting three epiphyses, one for the coracoid process, one for the acromion, and one for the lower angle of the bone, the ossification of which begins soon after puberty, their union with the body of the bone taking-place between the ages of twenty-two and twenty-five years. The Clavicle has an epiphysis at its sternal end, which begins to form between the eighteenth and twentieth years, and is united to the rest of the bone a few years later. The consolidation of the Humerus is completed rather earlier, the large piece at the upper end, which is formed by the coalescence of the ossific centres of the head and two tuberosities, unites with the shaft at about the twentieth year, whilst its lower extremity is completed, by the junction of the external condyle and of the two parts of the articulating surface (previously united with each other), at about the seventeenth year, and by that of the internal condyle in the year following. The superior epiphyses of the Radius and Ulna unite with their respective shafts at about the age of puberty, the inferior, which are of larger size, at about the twentieth year. The epiphyses of the Metacarpal and Phalangeal bones are united to their principals at about the twentieth year.—In the *Lower Extremities* the process of ossification is completed at nearly the same periods as that of the corresponding parts of the upper. The consolidation of the Ilium, Ischium, and Pubis, to form the Os Innominatum, by the ossification of the triradiate cartilage that intervenes between them in the acetabulum, does not take-place until after the period of puberty; and at this time additional epiphyses begin to make their appearance on the crest of the ilium, on its anterior inferior spine, on the tuberosity of the ischium, and on the inner margin of the pubes, which are not finally joined to the bone until about the twenty-fifth year.

978. The rapid increase in *Viability* which shows itself in both sexes up to the age of puberty, its rapid decline from that point, and its subsequent increase in the male up to the age of thirty, have been already pointed-out (§ 913). The disorders to which the organism is most subject during the several periods which have now been considered, are by no means the same for each. In early Childhood, when there is a great demand for the activity of the Digestive and Assimilative functions, and these have to be exercised upon nutriment to which their organs are not yet accustomed, we find derangements of those organs to be among the most common of all maladies; these may be serious enough in themselves to constitute dangerous and even rapidly-fatal diseases, but even when they do not take these acute forms, a foundation is often laid in habits of perverted Nutrition thence arising, for disorders of a more chronic nature (especially those depending on the Tubercular diathesis, § 376), which may not manifest themselves for many years afterwards. The peculiar activity of the nervous centres, which is prolonged from Infancy into early Childhood, involves a continued liability to derange-

ments of *their* nutrition or of their functions; and thus it happens that in young children of scrofulous temperament, it is either in the mesenteric glands, or in the brain or its membranes, that tubercular deposit first takes place. The second Dentition, like the first, is often accompanied with a great deal of constitutional disturbance; especially in such individuals as are suffering from defective Nutrition, or from an irritable state of the Nervous System. In the former case, there is a special proneness to Tubercular disease;* in the latter, to Epilepsy, Chorea, or some other form of disorder of the nervous centres, the connection of which with Dentition is shown by its abatement when that epoch has passed. A large part of the sickness and mortality, however, which presents so high a rate during the whole period of Childhood, is due to various forms of Zymotic disease, especially the Exanthemata and Infantile Remittent Fever, and to their *sequelæ*.—The attainment of Puberty in the Male sex is not usually attended with any specific tendency to disease; nor would it probably be in the Female, if her mode of life were more accordant with the rules of health. Although disorder of the Menstrual function is one of the most common phenomena of female youth, yet it is undoubtedly to be looked-upon more frequently as a symptom of general defect of nutrition (and especially of an impoverished condition of the blood), than as itself constituting a disease. The extraordinary reduction in the probability of life, indicating a large mortality, during the years which immediately succeed puberty, seems to depend in great degree, in the Male, upon the premature use of his generative powers, and upon his entrance upon the active employments of life before his constitution has received that invigoration which results from the completion of his bodily development; whilst in the Female, it is very commonly attributable to the accumulation of unhealthy influences, which begin to 'tell' upon the powers of her system, when its germinal capacity no longer ministers to its active regeneration. It is *then*, in both sexes, though from causes whose immediate nature is different, that the Tuberculous diathesis is prone to develope itself with peculiar intensity, and that, by fixing upon the Respiratory organs, it produces the most rapidly-fatal alterations in structures whose integrity is essential to life.

979. *Period of Maturity*.—The cessation of growth, and the completion of the developmental processes, which indicate the attainment of *Manhood*, are accompanied by a marked increase in the general vigour of the organism, and by a special augmentation in the power of *endurance* in the exercise of the Animal faculties. With the exception of those parts of the fabric whose utility was confined to the earlier periods of its development, we find every organ now presenting its greatest capacity for sustained activity; and thus it is from the characters which each presents at this period, that we base our ideas of its *typical* perfection of structure and composition. All the previous changes which the organism has undergone, both as a whole, and in its separate parts, concur to the attainment of this perfection, as we have especially seen in regard to the evolution of the solid framework of the body; and every subsequent

* It is a very significant circumstance, that of the many specimens of the Anthropoid Apes which have been brought alive to this country, not one has survived its second dentition, and that, in almost every case, it has been by tubercular disease that their lives have been thus prematurely cut-off.

change, as we shall presently perceive (§ 981), involves a deterioratio from it. The whole *nisus* of development, during this period, appears t be directed towards the *maintenance* of the organism in the state whic it had acquired at its commencement; by the regeneration of its tissues a fast as they undergo disintegration, and by the renovation of its vital for in proportion as this is expended. There is no longer any capacity fo the production of new organs, and comparatively little for the augmenta tion of those already existing; the increase of the Uterine and Mammar structures, during the period of gestation, being the most importa examples of formative power, and these presenting themselves in the se in which there is least of nervo-muscular activity and of general vigou We should infer then, that the 'germinal capacity' is now on the declin and this further appears from the diminished energy and completene with which the reparative processes are performed, as compared with th mode in which they are executed during the period of growth. There i consequently a less demand for alimentary material (allowance being mad for the augmented bulk of the body) than during the previous period and the dependence of life upon a constant supply of aliment is fa less close. Moreover, the ordinary rate of waste or degeneration of tiss is now much less rapid than during the period of growth; for we hav seen that decay and removal, in the latter case, are among the ver conditions of increase; whilst in the former, they proceed, for the mo part, only from the expenditure of the vital powers of the tissues, co sequent upon their functional activity. Hence it is upon the degree i which the *Animal* powers are exercised, that the demand for food chief depends in the Adult; the sole purpose of the Organic or Vegetati operations being (so to speak) to keep the apparatus of Animal life, no fully developed, in working order. The relative activity of the differe parts of this apparatus is now somewhat modified. The *observin faculties* no longer possess the same pre-eminence; the *emotional sensi bility* is less readily excited; but the *intellectual powers* now act, in th modes which have become habitual to them, with a sustained vigo and completeness which they never previously possessed. And so, whil the muscles are not so easily excited to contraction, and new combina tions of movement are acquired with far more difficulty than during th period of growth and development, the force which they can generate b their contraction is augmented, and this force can be kept-up for a muc longer time in adults than in younger subjects.

980. The duration of the period over which this 'maintenance' ma be protracted, without any sensible deterioration, depends in great degr upon the due observance of all the conditions of health. If the vario mental and bodily faculties are duly exercised, without being overtaske —if an amount of Sleep adequate to their periodic renovation be regularl taken,—if a sufficient but not excessive quantity of wholesome food b ingested at appropriate intervals,—if the functions by which the blood i prepared, and those by which it is kept in purity, be duly performed,— if all such noxious agents as foul air, alcoholic liquors, tobacco-smok be kept at a distance,—and there be no constitutional predisposition t disease on the one hand, nor any exposure to extraneous morbific caus on the other,—it may be fairly anticipated that the bodily and ment vigour may be sustained with little deterioration during a long successi

of years. The circumstances that most tend to premature decline, are, on the one hand, excessive exertion either of the mental faculties or of the generative power; or, on the other, undue indulgence in food, or in stimulating drinks, or in any practice that tends to disorder the Organic functions, especially by exciting them to undue activity. Every one who, in *any* of these modes, may "live too fast," is almost certain to pay the penalty, in an abbreviation of his term of vigorous activity; which may be either brought to a sudden and final close by fatal disease, or may be prematurely reduced by more gradual decay. And this tendency will of course be more decided, the greater is the amount, and the larger the combination, of those departures from the Laws of Health which give rise to it.

951. *Period of Decline.*—The *decline of life* exhibits a much more obvious diminution of the whole vital power of the organism; for not only is its formative activity now greatly reduced, but its nervo-muscular energy and general vigour progressively diminish, and its generative power becomes enfeebled, or ceases entirely (§§ 846, 854). Of this diminution in formative power, we have evidence in the entire absence of any attempt at new development, in the less perfect and more tedious manner in which the losses of substance occasioned by disease or injury are recovered from, and in the gradual deterioration of the organism in general. The tissues which are rendered effete by their functional activity, are not any longer replaced in their normal completeness; for either the quantity of new tissue is inadequate, so that the bulk of the organs is obviously reduced; or their quality is rendered imperfect, by the production of structures in various phases of degeneration, in place of those which had been previously developed in the fullest completeness. The inferiority of Nervo-muscular energy and of general vigour are thus evidently the result of the deficiency, and not (as in the period of growth) of the excess, of formative power; and in proportion as the 'waste' of the tissues, consequent upon their functional activity, is more rapid than their renovation, a progressive loss of substance must take place. The forms of Degeneration most commonly met with in advanced age, are the *fatty* and the *calcareous*. The former (§ 349) is extremely prone to show itself in those organs whose integrity of structure is peculiarly important to health, and whose deterioration interferes directly with the *vital* properties of their component tissues. Thus we observe it in the Muscular apparatus generally, but pre-eminently in the walls of the Heart; and in proportion as its contractile fibre has been replaced by particles of fat, must the vital energy of any muscle be lowered. So, again, we find the same degeneration in the Liver, Kidney, and other parts of the Glandular apparatus; the proper secreting action of which is impaired in the ratio of the substitution of fat for the proper Glandular elements. But it may also lead to most serious derangements of the vital functions, by its interference with the purely mechanical actions of certain parts of the organism; thus, fatty degeneration of the walls of the Blood vessels is one of the most frequent causes of those extravasations of blood in the nervous centres, which give rise to the apoplexy and to the various forms of paralysis so common among the aged; and the same change occurring in the Bones, gives them that peculiar brittleness which they frequently exhibit in advanced periods of life. That general decline of

the vital powers, which has received the name of 'climacteric disease' appears traceable to the same source.*—The tendency of the calcareous degeneration (which especially affects the Cartilaginous and Fibrous tissues) is almost exclusively to interfere with the *mechanical* adaptation of the organism, producing an injurious rigidity in various structures which require a greater or less amount of flexibility for the normal performance of their functions. Thus it is very common for the cartilages of the ribs to become ossified in advanced life, so as to interfere with the free movement of the walls of the thorax; and the thyroid cartilage of old people are frequently converted into bone, producing a roughness of the voice, and deficiency of the power of modulating it. The intervertebral substance (which is partly cartilaginous and partly fibrous) not unfrequently becomes solidified in the lumbar region, as do also the spinal ligaments, so that several of the lower vertebræ are firmly anchylosed to each other and to the sacrum; and a like change often takes-place in the pelvic articulations, so that the pelvis and the lower part of the spine become one continuous mass of bone, destitute of flexibility or yieldingness in any part. In like manner, the cranial sutures often become obliterated, and calcareous deposits occur in the duplicature of the dura mater forming the falx and tentorium. A large amount of this kind of change may take-place, without any serious interference with the Organic functions, although it tends to curtail the Animal powers. When the calcareous degeneration, however, extends itself to the vital organs, the interruption which it occasions in their actions may be fatal; thus, next to fatty degeneration, there is probably no more frequent cause of failure of the heart's action, or of extravasation from the blood-vessels, in old persons, than ossification of the valvular apparatus of the former, depriving it of the flexibility which is essential to its proper action, or of the fibrous walls of the latter, imparting to them a brittleness which predisposes to rupture.

982. Thus, then, with the advance of Old Age, the organism becomes progressively more and more unfit for the active performance of its vital operations; a gradual weakening is observable in the Mental as well as in the Corporeal energy; and a retardation becomes obvious in the current of Organic life. The mind is far less active than in the periods of Maturity; the perceptions are dull, the feelings comparatively obtuse (save where some dominant emotion has gained possession, through the previous habit of yielding to it), the intellectual powers cannot be so readily put in action, and the imagination loses its vividness. There are few instances in which any great works, either literary or artistic, have been executed after the age of threescore. Still, the experience of a long life gives value to the judgment; and the counsels of the old, where the bearings of the question can be fully understood, deserve the respect of the young, more especially in cases where temporary ardour of feeling tends in the latter to supersede the dictates of their calmer reason.—The mental torpor is correlated, there seems no reason to doubt, with changes in the condition of the Nervous substance, which impair its original activity; and like changes, occurring in the Muscular substance, diminish its capacity for physical exertion. Hence there is, on the one hand, a

* See Mr. Barlow's 'General Observations on Fatty Degeneration,' in the "Medical Times and Gazette," May 15, 1852.

marked diminution in the demand for food; on the other, a like diminution in the rate of the excretory processes, as is seen especially in the exhalation of carbonic acid (§ 316 III.) and in the excretion of Urea (§ 411); and in accordance with all these reductions, there is a greatly-diminished power of sustaining the heat of the body, the temperature of which consequently becomes liable to a serious depression from external cold.* This retardation of vital activity gradually becomes more and more marked, until, if neither accident nor disease should intervene, the current stops of itself; the formative power seems to undergo a progressive exhaustion, until no assistance from artificial heat, no supply of the most nutritious food, can any longer avail for the generation of new tissue; the nervo-muscular energy gradually declines, until at last even those actions on which the circulation and respiration entirely depend can no longer be performed; and, with the cessation of these functions, the Life of the entire organism becomes extinct.—Such we may consider to be the mode in which *Death* normally occurs. Various abnormal influences, however, remain to be considered, which may bring-about this final result at an earlier period, and in different modes (Chap. XIX.).

* The experience of the first two months of the present year, has afforded a remarkable confirmation of the statement previously made (§ 443) respecting the influence of continued Cold in raising the rate of mortality. The mean weekly temperature for six weeks having been 28.4° (or 9.4 below the average of the season), the excess in the number of deaths above the average, corrected for increase of population, has been nearly 2000, or more than 300 per week. The mode in which this excess is distributed, is not a little curious; the numbers having been as follows:—

	Actual excess of deaths by cold.	Deaths by cold to 100,000 living at each age.
All Ages	1968	77
0–20	419	40
20–40	200	22
40–60	392	87
60–80	752	512
80 and upwards	205	2073

It is only, of course, when the actual number of *deaths* is compared with the number *living at each age*, that the relative fatality of cold at different periods of life can be rightly estimated; from this comparison we see that its *minimum* influence is exerted on individuals between 20 and 40 years of age, and its *maximum* (nearly 100 times as great) on those above 80, the fatality resulting from the reduction of temperature being doubled every nine years after the age of 40. The diseases which chiefly contributed to this excess of mortality were pneumonia, bronchitis, and asthma; but the deaths from many others (chiefly chronic diseases) were in excess, so that it may be affirmed that cold brings quickly to a fatal end many maladies which it does not directly induce.—See the weekly Report of the Registrar General for March 3, 1855.

CHAPTER XIX.

OF DEATH.

983. We have seen it to be inherent in the very nature of Vital Action, that it can only be sustained during a *limited period* by any Organized body; for although the duration of certain structures may be prolonged, and their vital properties retained, almost indefinitely, yet this is only when the withdrawal of all extraneous agencies has reduced them to a condition of complete inactivity.* The Organized fabric, in fact, is at the same time the *instrument* whereby Vital Force is exercised, and the *subject* of its operation; and of this operation, *decline* is no less a constituent part than *development*, and *Death* is its necessary sequence. Hence, in the performance of each one of those Functions whose aggregate makes-up the Life of Man, the particular organ which ministers to that function undergoes a certain loss by the decline and death of its component tissues, and this the more rapidly, in proportion to the activity of the changes which are effected by their instrumentality. But if the regenerative processes be also performed with due vigour, no deterioration of the organ is manifested, since every loss of substance is compensated by the production of an equivalent amount of new and similar tissue. This regenerative power, however, gradually diminishes with the advance of years; and thus it happens that the entire organism progressively deteriorates (§ 981), and that Death at last supervenes from a general failure of the vital powers, rather than from the perversion or cessation of any one class of actions in particular.

984. But Death may occur at any period of Life, from some local interruption produced by disease or injury in the regular sequence of vital actions; such interruption extending itself from the part in which it commences, to the organism in general, in virtue of that intimate mutual dependence of one function upon another, which is characteristic of all the higher orders of living beings. The death of the body as a whole, which may be appropriately designated *Somatic*† death, becomes a necessary consequence of the death of a certain part of it, or *Molecular* death, only when the cessation of activity in the latter interferes with the elaboration, the circulation, or the depuration of the Blood, which supplies not merely the nutritive *pabulum* to every part of the organism, but also the oxygen which is essential to the activity of the Nervo-muscular apparatus. Thus, even in the higher animals, the death or removal of the limbs, although they may constitute (as in Man) a large proportion of the fabric, is not necessarily fatal; because it involves no interruption, either in the nutritive operations of

* See the section on 'Dormant Vitality' in Princ. of Gen. Phys.

† This term was first suggested by Dr. Prichard, in place of the less accurate term 'systemic' which was previously in use. (See "Cyclop. of Anat. and Physiol.," vol. I, p. 791.)

the viscera, or in the sensorial functions of the brain.* On the other hand, the destruction of a certain minute portion of the Nervous centres, or such a lesion of the Heart's structure as would be trivial in almost any other organ, may be the occasion of immediate death; because these changes arrest the Respiratory movements, or interfere directly with the action of the Heart, so as to bring the flow of blood to a stand. It sometimes happens, however, that life may be prolonged after the death or removal of some important organ, in consequence of the power which some other possesses of discharging its function; thus we find that, in Man, the kidneys seem occasionally to take upon themselves the elimination of the constituents of bile from the blood (§ 388); and in the Frog, the skin can perform part of the office of the lungs, so as to effect the aeration of the blood in a sufficient degree to prolong life for some time, unless the temperature be elevated.†

985. But although the vital activity of every part of the body is dependent upon a due supply of circulating fluid, yet this dependence is usually not so close as to involve the *immediate* suspension of vital activity, or *Molecular Death*, in every part, whenever the general Circulation shall have been brought to a stand. For we have distinct evidence of the persistence of vital changes in various organs and tissues of the body, after the death of the body at large; as is manifested in the performance of ciliary and of muscular movements (PRINC. OF GEN. PHYS.), in acts of secretion and perhaps even of nutrition,‡ in the maintenance of the local circulation (§ 269), and in the generation of animal heat (§ 428); and the fact is even yet more remarkably manifested in the reunion (even after the lapse of some hours) of parts that have been entirely severed, such as fingers or toes, noses or ears, by adhesion between the cut surfaces when brought into apposition, which could not take place if the severed part were already *dead*.

986. The permanent and complete cessation of the Circulating current, which essentially constitutes *Somatic* Death, may be directly or indirectly consequent upon several distinct causes.—In the *first* place, it may be due to failure in the propulsive power of the Heart, which constitutes *Syncope*. This failure may occur either (*a*) in consequence of a loss of the proper irritability of the Muscular tissue, or (*b*) through the supervention of a 'tonic spasm,' the organ remaining rigidly contracted

* The Author has been informed by Dr. Daniell, that it is not at all uncommon, in Negroes who are in the last stage of the adynamic fevers of the African coast, for death and decomposition to extend gradually upwards from the extremities to the trunk; so that the former may be in a state of absolute putrescence, before the respiration and circulation have been brought to a stand; and he learns from Prof. Jackson of Philadelphia, that he has more than once witnessed the same occurrence.

† That such cannot take place in Man, is due not merely to the far less complete adaptation of his skin for the aeration of the blood, but also to the difference in the type of his circulation, which causes the arrest of blood in the pulmonary vessels to produce a stagnation of the entire current.

‡ Thus Mr. T. Bell mentions ("History of British Reptiles," p. 61), that having been engaged in the careful dissection of the poison apparatus of a large Rattlesnake, although the animal had been dead for some hours, and the head had been taken off immediately after death, yet the poison continued to be secreted as the dissection proceeded, so as to require to be occasionally dried off with a bit of sponge. A growth of Hair is said to have been noticed in several instances after death; and if the temperature of the surrounding medium be not too low for the vital activity of the hair-bulbs, there seems no adequate reason why this should not take place.

without its usual alternation of relaxation. The phenomena attendi death in the two cases are not dissimilar, when the loss of irritability sudden and immediate (as when it arises from violent impressions on t nervous system), for the individual suddenly turns-pale, falls-back drops-down, and expires with one gasp. But under the former co dition, the heart is found *flabby*, sometimes empty, sometimes distend with blood, both cavities being equally filled; whilst in the latter, t heart is contracted and hard, containing little or no blood, as when the state of *rigor mortis*.—The cause of the loss of irritability, wh sudden, usually lies in the influence of a 'shock' transmitted throu the Nervous system, and originating either in some severe lesion of i central organs or of its peripheral expansion (§ 238), or in a deficien of its supply of blood or diminution of its usual pressure (such a produced by rapid detraction of blood, especially in the erect postu by the rapid removal of the fluid in ascites without the substitution artificial pressure, or by suddenly rising into the erect posture aft prolonged recumbency,* still more, after long stooping), or in so powerful mental emotion, either exciting or depressing. A more gradu effect of the same kind is produced by severe lesions of the intern organs (such as rupture of the uterus), which often prove fatal by t general 'collapse' thus induced, rather than by the disturbance whi takes-place in their own proper functions; and this seems to be t usual *modus operandi* of corrosive poisons, whose effect upon t heart's action resembles that produced by severe burns of the surface children. The influence of the proper *sedative* poisons, however,—su as digitalis, tobacco, aconite, and upas,—seems to be directly exerte through the blood, upon the tissue of the heart itself, and the same probably the case with some of those 'morbid poisons,' whose intr duction into the system gives rise to diseases of the most intense adynamic type, such as Malignant Cholera, in which the 'collapse' i out of all proportion to any local lesion. But, again, the loss of th Heart's irritability may be a gradual process, resulting from the dete rioration of its tissue by fatty degeneration or by simple atrophy an this last condition may be due to deficiency of blood, as happens i chronic starvation and diseases of exhaustion, in which the failure the circulation seems due to the weakening of the heart's power and t the lowering of the quantity and quality of the blood, acting as concu rent causes, the condition thus induced being appropriately designat *Asthenia*. In all cases it is to be observed, that when the Vital powe have been previously depressed, a much slighter impression on th Nervous system is adequate to produce Syncope, than would be requir when it is in a state of full vigour.—The causes of the tonic spasm the heart have not been clearly made-out; but it seems producible, li the more common form of Syncope, by agencies operating through th Nervous system; thus it has supervened upon the ingestion of a lar quantity of cold water into the stomach.

987. Somatic Death may be occasioned, *secondly*, by an obstructi

* Hence it is that great caution should be exercised, in allowing patients wh are co valescent from acute diseases to rise into the erect position, many cases of fatal sy having been thus induced. The state of general debility, and the continued recumben both favour this result, especially in persons advanced in life.

to the flow of blood through the capillaries of the lungs, constituting *Asphyxia* (§ 326); and this may be consequent upon a disordered state of the lungs themselves, or upon suspension of the respiratory movements through affections of the Nervous centres. It is in this mode that most fatal disorders of the Nervous System produce death, except when a sudden and violent impression occasions a cessation of the heart's power; thus in Apoplexy, Narcotic Poisoning, &c., death results from the paralyzed condition of the Medulla Oblongata; whilst in Convulsive diseases, the fatal result generally ensues upon a spasmodic fixation of the respiratory muscles.—*Thirdly*, Somatic death may be occasioned by a disordered condition of the *Blood* itself (§ 194), which at the same time weakens the power of the Heart, impairs the activity of the Nervous system, and prevents the performance of those changes in the systemic Capillaries, which afford a powerful auxiliary to the circulation. This is Death by *Necræmia*.*—*Fourthly*, Somatic death may result directly from the agency of *Cold*, which stagnates *all* the vital operations of the system. Where the cooling is due to the agency of an extremely low external temperature, which acts first upon the superficial parts, there is reason to think that the congestion of the internal vessels thereby induced, occasions a torpid condition of the Nervous centres, and that the cessation of the Circulation is immediately due to Asphyxia. But when the cooling is gradual, and the loss of heat is almost equally rapid throughout, it is obvious that the stagnation must be universal, and that no cessation of activity in any one part is the occasion of the torpor in the functions of the remainder. It is in this manner that death ordinarily results from Starvation, and not by the weakening of the heart's action, as commonly supposed; the proofs of this have been already stated (§ 433).

988. As a general rule, we find that the more active the changes which normally take place in any tissue during life, the more speedily does its *Molecular* Death follow Somatic Death, the requisite conditions of its vital action being no longer supplied to it. Thus we observe that, in Cold-blooded animals, the supervention of Molecular upon Somatic death is much less speedy than it is in Birds and Mammals. This seems due to two causes. In the first place, the tissues of the former, being at all times possessed of a lower degree of vital activity than those of the latter, are disposed to retain it for a longer time; according to the principle already laid-down. And, secondly, as the maintenance of a high temperature is an essential condition of the vital activity of the tissues of warm-blooded animals, the rapid cooling of the body after Somatic death is calculated to extinguish it speedily; and that this cause has a real operation, is evinced by the influence of artificial warmth in sustaining the vital properties of separated parts.—The rapidity, however, with which Molecular death follows the cessation of the general circulation, will be influenced by a variety of causes; but especially by the degree in which the condition of the solids and fluids of the body has been impaired by the mode of death. Thus in Necræmia, Asthenia, and death by gradual cooling, Molecular and Somatic death may be said to be simultaneous; and the same appears to be true of death by sudden and violent impressions on the Nervous system (§ 238). But in many

* See Dr J. C. B. Williams's "Principles of Medicine," 2nd edit., p. 464.

cases of death by causes which operate by producing a more grad[illegible] Syncope or Asphyxia, the tissues and blood having been previously [illegible] a healthy condition, Molecular death may be long postponed; and [illegible] cannot be quite certain that it has supervened, until signs of act[illegible] decomposition present themselves.

989. When Molecular death takes-place in an isolated part, it m[illegible] result from some condition peculiar to that part, and not primar[illegible] affecting the body in general. Thus we may have Gangrene or Mort[illegible] cation of a limb as a direct result of the application of severe cold, [illegible] of an agent capable of producing chemical changes in its substance, [illegible] of violent contusions occasioning mechanical injury, or, again, from [illegible] interruption to the current of nutritive fluid; or, further, from so[illegible] ill-understood stagnation of the nutritive process, which manifests it[illegible] in the spontaneous death of the tissues without any assignable cause, [illegible] in some cases of senile gangrene. Sometimes we are enabled to tr[illegible] this stagnation to a disordered condition of the circulating fluid; as [illegible] the gangrene resulting from the continued use of the 'ergot' of rye [illegible] wheat, but we can give no other account of the almost invariable co[illegible] mencement of such gangrene in the extremities, than we can of [illegible] selection of lead, introduced into the blood, by the extensors of the fo[illegible] arm.—If Mortification or Molecular Death be once established in [illegible] part, it tends to spread, both to contiguous and to distant portions of [illegible] body. Thus we have continually to witness the extension of gangrene [illegible] the lower extremities, resulting from severe injury or from the use [illegible] the ergot, from the small part first affected, until the whole limb [illegible] involved; and this extension is easily accounted for, by our knowled[illegible] of the tendency of organic substances in the act of decomposition, [illegible] produce a similar change in other organic substances subjected to [illegible] influence of proximity to them. And the propagation of the gangrene[illegible] tendency to remoter parts, is obviously due to the perversion of [illegible] qualities of the Blood, which results from a similar cause.*

990. It is quite certain that an *apparent* cessation of *all* the vi[illegible] functions may take-place, without that entire loss of vitality, which wo[illegible] leave the organism in the condition of a *dead* body, liable to be speedi[illegible] disintegrated by the operation of chemical and physical agencies. T[illegible] state of Syncope is sometimes so complete, that the heart's action can[illegible] be perceived, nor any respiratory movements be observed, all conscio[illegible] ness and power of movement being at the same time abolished; and [illegible] recovery has spontaneously taken place, which could scarcely have be[illegible] the case, if *all* vital action had been suspended.—It is not a li[illegible] remarkable, that certain individuals have possessed the power of *volu[illegible] tarily* inducing this condition. The best-authenticated case of this ki[illegible] is that of Col. Townsend, which was described by Dr. George Cheyne[illegible] who was himself the witness of the fact. But statements have be[illegible] recently made respecting the performances of certain Indian Fake[illegible] which are far more extraordinary; it being demonstrated, if these a[illegible]

* On the proximate causes of Death, see especially the Art. 'Death,' by Dr. Sym[illegible] in the "Cyclop. of Anat. and Phys.," vol. i., the first chapter of Prof. Alison's "O[illegible] of Pathology and Practice of Medicine," and Dr. C. J. B. Williams's "Principles of M[illegible] cine," 2nd edit., pp. 452-469.

† See his "Treatise on Nervous Diseases," p. 307.

tions are to be credited,* that the Human organism may not only be voluntarily reduced to a state resembling profound collapse, in which there appears to be a nearly complete suspension of all its vital operations, but may continue in that condition for some days or even weeks, until, in fact, means are taken to produce resuscitation.—Another form of apparent death, the existence of which appears to be well authenticated, is that sometimes designated as 'Trance' or 'Catalepsy,' in which there is a reduction of all the Organic Functions to an extremely low ebb, but in which Consciousness is still preserved, whilst the power of voluntary movement is suspended, so that the patient, though fully aware of all that is being said and done around, is unable to make the least visible or audible sign of life.† It is impossible, in the present state of our knowledge, to give any satisfactory account of these states; but some light appears to be thrown upon them by certain phenomena of artificial Somnambulism, 'hypnotic' or 'mesmeric' (§§ 694–6), for in this condition, there is sometimes an extraordinary retardation of the respiratory movements and of the pulsations of the heart, which, if carried further, would produce a state of complete collapse; and its self induction is suspected by Mr Braid to be the secret of the performance of the Indian Fakeers just referred to.

991. The signs by which *real* is certainly distinguishable from *apparent* Death, are not numerous, a large proportion of those commonly relied-on being fallacious; but they are conclusive.—In the first place, it is to be remarked that no reliance is to be placed, for the reasons already mentioned, upon the apparent cessation of the Heart's action and of the Respiratory movements; since the reduction of these to so low a condition that they are no longer distinguishable, is by no means incompatible with the persistence of vitality. A surer test, however, is afforded by the condition of the *Muscular* substance; for this gradually loses its irritability after real Death, so that it can no longer be excited to contraction by

* See a collection of these cases, directly obtained from British officers who had been eye-witnesses of them in India, by Mr. Braid, in his "Observations on Trance, or Human Hybernation," 1851. In one of these, vouched for by Sir Claude M. Wade (formerly political agent at the Court of Runjeet Singh), the Fakeer was buried in an underground cell, under strict guardianship, for *six weeks*; the body had been twice dug up by Runjeet Singh during the period of interment, and had been found in the same position as when first buried. In another case, narrated by Lieut. Boileau, in his "Narrative of a Journey in Rajwarra, in 1835," the man had been buried for ten days, in a grave lined with masonry and covered with large slabs of stone, and strictly guarded; and he assured Lieut. B. that he was ready to submit to an interment of a twelvemonth's duration, if desired. In a third case narrated by Mr. Braid, the trial was made under the direct superintendence of a British Officer, a period of nine days having been stipulated for on the part of the devotee; but this was shortened to three at the desire of the Officer, who feared lest he should incur blame if the result was fatal. The appearance of the body when first disinterred, is described in all instances as having been quite corpse-like, and no pulsation could be detected at the heart or in the arteries; the means of restoration employed were chiefly warmth to the vertex, and friction to the body and limbs. It may be remarked that the possibility of the protraction of such a state (supposing that no deception vitiates the authenticity of the narratives referred to) can be much better comprehended as occurring in India, than as taking place in this country; since the warmth of the tropical atmosphere and soil would prevent any serious loss of heat, such as must soon occur in a colder climate, when the processes whereby it is generated are brought to a stand.

† Several such cases are recorded in Dr. H. Mayo's "Letters on the Truths contained in Popular Superstitions," and also by Mr. Braid, Op. cit.

electrical or any other kind of stimulation; and the loss of irritability is succeeded by the appearance of cadaveric rigidity. So long, then, as the muscle retains its irritability and remains free from rigidity, so long we may say with certainty that it is *not dead;* and the persistence of its vitality for an unusual period, affords a presumption in favour of the continuance of some degree of vital action in the body generally; whilst on the other hand, the entire loss of irritability, and the supervention of rigidity, afford conclusive evidence that death has occurred. The most satisfactory proof, however, is given by the occurrence of *putrefaction;* this usually first manifests itself in the blue-green coloration of the cutaneous surface, especially the abdominal; but it speedily becomes apparent in other parts, its rate being usually in some degree of accordance with the external temperature, though also much influenced by the previous condition of the solids and fluids of the body, these having been sometimes left by diseased actions in a state that renders them peculiarly prone to disintegration (§ 72).

992. With the final restoration of the components of the Human Organism to the Inorganic Universe, in those very forms (or nearly so) in which they were first withdrawn from it, the Corporeal Life of Man, of which it has been the object of the foregoing Treatise to sketch the leading features, comes to a final close. But the Death of the Body is but the commencement of a new Life of the Soul; in which (as the religious physiologist delights to believe) all that is pure and noble in Man's nature will be refined, elevated, and progressively advanced towards perfection; whilst all that is carnal, selfish, and degrading, will be eliminated by the purifying processes to which each individual must be subjected, before Sin can be entirely subjugated, and Death can be completely "swallowed up of Victory."

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